Procedures and Standards for Determining Revegetation Success on Surface-Mined Lands in Texas

SURFACE MINING AND RECLAMATION DIVISION

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I. Introduction

This document describes procedures and standards for determining revegetation success on reclaimed surface mined lands in Texas as required by and in accordance with TEX. NAT. RES. CODE §§134.041, .092(a)(19) & (20), and .104 (Vernon's Supp. 1997), and §§12.390 through 12.395, and 12.399 of the Texas Coal Mining Regulations (TCMR). Revegetation success must be demonstrated by using the revegetation standards and statistically valid sampling techniques for measuring success selected by the Railroad Commission of Texas (Commission). This document presents the set of procedures and standards for determining revegetation success that are currently approved by the Commission.

The use of the methods contained in this document by mining companies operating in Texas will satisfy the Commission that adequate data collection methods have been used for determining revegetation success for purposes of releasing reclamation performance bond funds. Mining companies may propose alternative procedures for sampling and analysis of vegetation data; however, the use of alternative methods will require prior approval by the Commission and must be included in the approved regulatory program.

II. Regulatory Requirements

Under the Texas Surface Coal Mining and Reclamation Act, the permittee is responsible for meeting revegetation success in accordance with the performance standards described at §§134.092(a)(19) & (20) and 134.104. Texas Coal Mining Regulation §§12.390 through .395 and 12.399, were adopted to implement the performance standards for revegetation success as authorized in the Act. §134.013(a). Section 12.395(a) defines the standard by which revegetation success will be measured:

> (a) . . . . Success of revegetation shall be judged on the effectiveness of the vegetation for the approved postmining land use, the extent of cover compared to the cover occurring in natural vegetation of the area, and the general requirements of §§12.390 and 12.391 of this title . . .

Section 12.390(a) defines the general requirements that must be met for the vegetative cover established on all surface mining-disturbed lands:

> (a) The permittee shall establish on regraded areas and on all other disturbed areas except water areas and surface areas of roads that are approved as part of the postmining land use, a vegetative cover that is in accordance with the approved permit and reclamation plan and that is:
>
> (1) Diverse, effective, and permanent;
>
> (2) Comprised of species native to the area, or of introduced species where desirable and necessary to achieve the approved postmining land use and approved by the Commission;
>
> (3) At least equal in extent of cover to the natural vegetation of the area; and
>
> (4) Capable of stabilizing the soil surface from erosion.

Section 12.395(a)(1) and (2) define the requirements for the methodologies used for evaluating when the standard for revegetation success has been met:

> (1) Standards for success and statistically valid sampling techniques for measuring success shall be selected by the Commission.
>
> (2) Standards for success shall include criteria representative of unmined lands in the area being reclaimed to evaluate the appropriate vegetation parameters of ground cover, production, or stocking. Ground cover, production, or stocking shall be considered equal to the approved success standard when they are not less than 90% of the success standard. The sampling techniques for measuring success shall use a

90-percent statistical confidence interval (i.e., one-sided test with a 0.10 alpha error).

Section 12.395(b) defines the minimum standards for revegetation success for each recognized postmining land use:

(b) Standard for revegetated success. Standards for success shall be applied in accordance with the approved postmining land use and, at a minimum, the following conditions:

(1) For areas developed as grazingland, pastureland, or undeveloped land use, the ground cover and production of living plants on the revegetated area shall be at least equal to that of a reference area or such other success standards approved by the Commission.

(2) For areas developed as cropland, crop production on the revegetated area shall be at least equal to that of a reference area or such other success standards approved by the Commission;

(3) For areas to be developed for fish and wildlife habitat, recreation, shelter belts, or forest products, success of vegetation shall be determined on the basis of tree and shrub stocking and vegetative ground cover. Such parameters are described as follows:

(A) Minimum stocking and planting arrangements shall be specified by the Commission on the basis of local and regional conditions and after consultation with and approval by the State agencies responsible for the administration of forestry and wildlife programs;

(B) Trees and shrubs that will be used in determining the success of stocking and the adequacy of the plant arrangement shall have utility for the approved postmining land use. Trees and shrubs counted in determining such success shall be healthy and have been in place for not less than two growing seasons. At the time of bond release, at least 80% of the trees and shrubs used to determine such success shall have been in place for 60% of the applicable minimum period of responsibility; and

(C) Vegetative ground cover shall not be less than that required to achieve the approved postmining land use;

(4) For areas to be developed for industrial/commercial or residential land use less than 2 years after regrading is completed, the vegetative ground cover shall not be less than that required to control erosion; and

(5) For areas previously disturbed by mining that were not reclaimed to the requirements of this Subchapter and that are remined or otherwise redisturbed by surface coal mining operations, as a minimum, the vegetative ground cover shall be not less than the ground cover existing before redisturbance and shall be adequate to control erosion.

Section 12.3 defines the following words and phrases that are pertinent to this guidance document:

Disturbed area - an area where vegetation, topsoil, or overburden is removed or upon which topsoil, spoil, coal processing waste, underground development waste, or noncoal waste is placed by surface coal mining operations. Those areas are classified as disturbed until reclamation is complete and the performance bond or other assurance of performance required by Subchapter J of this Chapter . . . is released.

Land use - Specific uses or management-related activities, rather than the vegetation or cover of the land. Land use may be identified in combination when joint or seasonal uses occur. Changes of land use or uses from one of the following categories to another shall be considered as a change to an alternative land use which is subject to approval of the Commission.

(A) **Cropland**. Land used for the production of adapted crops for harvest, alone or in a rotation with grasses and legumes, and includes row crops, small grain crops, hay crops, nursery crops, orchard crops, and other similar specialty crops. Land used for facilities in support of cropland farming operations which is adjacent to or an integral part of these operations is also included.

(B) **Pastureland . . . .** Land used primarily for the long-term production of adapted, domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed. Land used for facilities in support of pastureland . . . which is adjacent to or an integral part of these operations is also included.

(C) **Grazingland**. Includes both grasslands and forest lands where the indigenous vegetation is actively managed for grazing, browsing, or occasional hay production. Land used for facilities in support of ranching operations which are adjacent to or an integral part of these operations is also included.

(D) **Forestry**. Land used or managed for the long-term production of wood, wood fiber or wood derived products. Land used for facilities in support of forest harvest and management operations which is adjacent to or an integral part of these operations is also included.

(E) **Residential**. Includes single- and multiple-family housing, mobile home parks, and other residential lodgings. Land used for facilities in support of residential operations which is adjacent to or an integral part of these operations is also included. Support facilities include, but are not limited to, vehicle parking and open space that directly relate to the residential use.

(F) **Industrial/Commercial**. Land used for:

(i) Extraction or transformation of materials for fabrication of products, wholesaling of products, or for long-term storage of products. This includes all heavy and light manufacturing facilities, such as lumber and wood processing, chemical manufacturing, petroleum refining, and fabricated metal products manufacturing. Land used for facilities in support of these operations which is adjacent to or an integral part of that operation is also included. Support facilities include, but are not limited to, all rail, road, and other transportation facilities.

(ii) Retail or trade of goods or services, including hotels, motels, stores, restaurants, and other commercial establishments. Land used for facilities in support of commercial operations which is adjacent to or an integral part of these operations is also included. Support facilities include, but are not limited to, parking, storage or shipping facilities.

(G) **Recreation**. Land used for public or private leisure-time use, including developed recreation facilities such as parks, camps, and amusement areas, as well as areas for less intensive uses such as hiking, canoeing, and other undeveloped recreational uses.

(H) **Fish and wildlife habitat**. Land dedicated wholly or partially to the production, protection, or management of species of fish or wildlife.

. . .

(J) **Undeveloped land . . . .** Land that is undeveloped, or if previously developed, land that has been allowed to return naturally to an undeveloped state or has been allowed to return to forest through natural succession.

Reference area. A land unit maintained under appropriate management for the purpose of measuring vegetation ground cover, productivity and plant species diversity that are produced naturally or by crop production methods approved by the Commission. Reference areas must be representative of geology, soil, slope, and vegetation in the permit area.

III. Vegetation Evaluation Procedures

This section identifies specific concepts and requirements to be followed in developing revegetation evaluation plans.

A. General Requirements

Ground cover and productivity (only herbaceous biomass) measurements **must be obtained during the growing season** of the primary vegetation species comprising the land use. Herbaceous productivity is estimated from only the current season's growth. Woody-plant stocking can be measured at any time. Ground cover corresponds to the area of ground covered (the vertical projection of the vegetation onto the ground surface) by the combined areal parts of standing permit-approved vegetation (dead or alive) and the litter that is produced naturally on site, expressed as a percentage of the total area of measurement (Vogel, 1987). The many small openings or interstices that are not actually overlain by plant parts within a canopy are not counted as cover, since these small uncovered interstices can account for a large percentage of the total ground area. Litter may be included as ground cover because it is part of the natural growth process; however, the litter component cannot exceed 15% of the total ground cover. Litter is defined as undecomposed or partially decomposed leaves, needles, or twigs that have been deposited on the ground surface as a result of natural processes of plant growth.

In order for species to be counted in ground cover measurements, the species must be on either of two lists found in the approved permit: 1) planting list that contains approved species which support the land use and 2) list of approved desirable invader species. The determination that a species can be counted in ground cover measurements should be made at the time of permit approval instead of at the time of vegetation surveys.

Rock fragments are considered ground surface cover during soil surveys (Soil Survey Division Staff, 1993), where ground surface cover is considered to be comprised of both vegetation and rock fragments. However, in surface-mining applications, only the vegetal component can be considered in ground cover measurements, since the TCMR specifically lists ground cover as a vegetation parameter. Rock fragments should still be included in vegetation surveys as a separate item, however, since rock fragments can "...have important effects on soil use and management " (USDA, 1993). Rock fragments equal to or smaller than a ¾- inch diameter (or 20 mm, the upper limit for medium-sized pebbles) are considered bare ground; however, rock fragments larger than ¾-inch in diameter will not count against the percentage cover calculated for surface-mining applications. The following illustrates the preceding methodology:

Example of hypothetical data from vegetation survey and the resulting calculations. Tally from 100 observation points:

- 64 points hit standing vegetation; all vegetation was from permit-approved species (most points were obtained from live plants, although some points intercepted above-ground biomass from the previous growing year; however, no differentiation was made between the live and dead standing vegetation, as long as it was from permit-approved species).
- 2 points hit standing vegetation, both points intercepted species that were not on the permit-approved list
- 17 points hit litter
- 7 points hit rock fragments that were greater than ¾-inch in diameter
- 10 points hit bare ground (7 points hit actual bare ground, 3 hit pebbles that were less than ¾-inch in diameter)

Reported results:

- Rock fragments (> ¾-inch diameter), 7 of 100 points; therefore, following calculations performed on 93 points. (Note: if too many points hit rock fragments, a statistically adequate sample size may not be achieved.)
- Bare ground, 10 of 93 points = 11%
- Permit-approved vegetation, 64 of 93 points = 69%
- Other vegetation, 2 of 93 = 2%
- Litter, 17 of 93 points = 18%
- Ground cover measurement would be 84% (permit-approved vegetation plus a maximum of 15% litter).

B. Data Collection

Regulations require that an estimate of statistical confidence be calculated along with all ground cover, productivity, or woody-plant stocking measurements. Consequently, the methods of vegetation surveys that are employed must comply with statistical conventions. The validity and/or uncertainty of statistical results are a function of the sampling methods followed during the vegetation surveys that are conducted; additionally, practical considerations must also play a role in the selection of sampling methods. The following are the fundamental approaches to collecting all vegetation data (except for whole-field harvesting and estimation of vegetative production from grazing data). All methods used to assess revegetation success must contain the following criteria:

1) All sample points must be chosen independently and have an equal chance of being chosen (random). Point selection should be objective and unbiased.
2) The number of sample points chosen to obtain precise estimates of the vegetative parameters is independent of the size of the area to be evaluated.
3) Sample units should be internally homogeneous (i.e. same land use, similar vegetation growth forms, comparable management, and similar edaphic characteristics).

The number of observation points needed to produce statistically-acceptable results depends on the vegetation parameter that is measured. Ground cover measurements will routinely require more observations than measurements for productivity and woody plant stocking rates. The procedures for determining sample numbers are discussed in Section IV.

C. Reporting of Vegetation Survey Data

The following describes the degree of detail that will be expected by the Commission when permittees submit revegetation data.

- All revegetation data should be accompanied by a map or aerial photograph that identifies the location of the vegetation survey transects.
- Ground cover measurements must include: 1) the total number of observations; 2) identify the outcome of each observation (either a "hit" or a "miss"), in order to determine the species composition; 3) identify the nature of each "hit" (either the plant species, litter, or rock fragments > ¾-inch diameter); 4) the estimated ground cover value; and 5) a one-sided 90% confidence interval (with a 0.10 alpha error) for the ground cover estimate. The confidence interval is only needed for ground cover estimates that are below the lowest acceptable value (90% of the technical standard) **or** in situations where the reclaimed area is compared to a reference area.
- Productivity measurements for forages, obtained from plot harvesting must include: 1) the total number of plots (i.e. quadrats); 2) oven-dry weights of the harvested biomass from each plot; 3) conversion of plot yield data to pounds per acre; 4) the mean and standard deviation of the yield data; and 5) a one-sided 90% confidence interval (with a 0.10 alpha error) for the standardized biomass yield. The confidence interval is only needed for productivity estimates that are below the lowest acceptable value (90% of the technical standard) **or** in situations where the reclaimed area is compared to a reference area.
- Productivity estimates for forages that are obtained by weighing a portion of the bales harvested must include: 1) the total number of bales harvested; 2) the acreage being measured; 3) the number of bales weighed to obtain average individual bale weights; 4) individual bale weights to obtain the average weight or number of truckloads and bales/truckload; 5) multiplication of the average bale weight by the total number of bales harvested - this will provide an estimate of the entire yield in pounds/acre; and 6) a one-sided 90% confidence interval (with a 0.10 alpha error) for the harvest yield. The confidence interval is only needed for productivity estimates that are below the lowest acceptable value (90% of the technical standard) **or** in situations where the reclaimed area is compared to a reference area.

- All productivity measurements must include documentation from a calibrated scale (i.e., scale manufacturer, model number, calibration date, date and time of productivity data collection, and individual performing the weighing).
- Productivity measurements (includes restored prime farmland soils) for cropland that involve plot harvesting must include: 1) the total number of plots; 2) the acreage being measured; 3) standard moisture percentage for the specific agricultural commodity; 4) standardized weights for crop yields, using the appropriate moisture contents for the specific commodities; 5) conversion of plot yield data to pounds per acre; 6) the mean and standard deviation of the yield data; and 7) a one-sided 90% confidence interval (with a 0.10 alpha error) for the standardized crop yield.
- Productivity measurements involving whole-field harvests must include: 1) the acreage being measured; 2) method of harvest; 3) conversion of total yield to pounds per acre. Note: no statistical calculations are needed for whole-field data.
- Woody-plant stem count measurements must include: 1) the total number of observations; 2) the area (either square feet or square meters) from which the individual observations were obtained; 3) identify the woody-plant species intercepted in each observation and their frequency; 4) conversion of the stem count data to stems per acre; 5) the mean and standard deviation of the stem count data; and 6) a one-sided 90% confidence interval (with a 0.10 alpha error) for the estimated stems per acre. The confidence interval is only needed for woody-plant stem estimates that are below the lowest acceptable value (90% of the technical standard) **or** in situations where the reclaimed area is compared to a reference area.

IV. Revegetation Success Evaluation and Measurement Methods

There are several vegetation parameters that must be evaluated for each designated postmine land use (Table 1). Measurement methods are presented for all vegetation parameters. Measurement results must be compared to either approved reference areas or technical success standards. The following subsections provide the approved methods for implementing the various evaluation methods for ground cover, productivity, and woody-plant stocking, beginning with the proper selection of observation points.

A. Selection of Observation Points for Collecting Vegetation Data

There are several approaches to locating measurement points for data collection. The observation points must be selected in an unbiased, objective fashion (i.e.: randomly), regardless of the method used to locate/select them. The number of observations (sampling intensity) is independent of the size of the area being evaluated. Two methods for selecting random points will be presented here, with illustrative examples of each. Pre-sampling plans for either method should be developed before going to the field, although the second method can be planned and implemented in the field if it is necessary to do so. Either observation location method is appropriate for all revegetation performance parameters. Additionally, the same set of observation points can be used for both ground cover and productivity measurements (both productivity and woody-plant stocking). The first method (*Random Point Sampling)* involves the selection of random points within the area to be evaluated and plotting of the points on a map or aerial photograph. The second method (*Baseline Sampling with Multiple Random Starts*) involves the random placement of a baseline within the target evaluation area, along with 5 randomly-placed transverse transects along the baseline.

A map or aerial orthophotograph (where there is equal scale over the entire photographic coverage) of the evaluation areas to be measured must be used when planning the vegetation surveys. The map scale should be equal or larger than 1 in. = 500 ft. A landmark on the map or aerial orthophotograph should be chosen to facilitate finding the survey starting point(s) in the field.

Table 1. List of land uses and the corresponding methods to evaluate revegetation success.

Land Use	Required Vegetation Parameters	Evaluation Method(s)
Grazingland and Pastureland	Ground Cover Productivity	Point-intercept 1. Mechanical/whole-field harvest 2. Harvest of plots (clipping) 3. Double-sampling 4. Grazing
Cropland: both non-prime farmland and restored prime farmland	Ground Cover - until row crops are planted Productivity	R.U.S.L.E. 1. Mechanical/whole-field harvest 2. Harvest of plots (clipping)
Forestry	Ground Cover Woody-Plant Stocking Rate	Point-intercept Plots, either rectangular or circular
Fish and Wildlife Habitat	Ground Cover Woody-Plant Stocking Rate	Point-intercept Plots, either rectangular or circular
Undeveloped Land	Ground Cover Woody-Plant Stocking Rate	Point-intercept Plots, either rectangular or circular
Commercial / Industrial	Ground Cover Woody-Plant Stocking Rate (when applicable)	R.U.S.L.E. † Plots, either rectangular or circular
Residential	Ground Cover Woody-Plant Stocking Rate (when applicable)	R.U.S.L.E. † Plots, either rectangular or circular
Recreation	Ground Cover Woody-Plant Stocking Rate (when applicable)	R.U.S.L.E. † Plots, either rectangular or circular

† R.U.S.L.E. -- Revised Universal Soil Loss Equation – used to estimate potential erosion.

1. Sample Number. The number of samples required will depend on the variability of the area being evaluated and achieving a statistically adequate sample size. The number of observation points (sample number) needed to produce statistically-acceptable results will depend on which vegetation parameter is measured, because there are different statistical equations involved. Ground cover measurements (binomial distributions) will routinely require more observations than measurements for productivity (normal distributions for both productivity and woody plant stocking). Ground cover measurements should ideally involve 100 observation points (for increased precision and ease of calculations), with a minimum of 75 points. Herbaceous productivity and woody plant stocking estimates require at least 15 measurements. Supplementary observation points may be necessary under the following two scenarios: 1) in ground cover, more than 100 observations will be necessary when the ground cover estimate falls below 75%, and 2) in areas with higher variability (for productivity or woody plant stocking), when a test for statistically adequate sample size ("sample adequacy") requires that additional samples be taken. The maximum sample number for binomial (ground cover) and normal (productivity and stem counts) distributions is 150 and 30, respectively. Any revegetation data that cannot achieve a statistically adequate sample size, after the maximum number of samples are taken, indicate that the measured area is too variable. In these cases, the evaluated area

may need to be examined to determine whether it was indeed internally homogeneous. Stratification of the evaluation area and its revegetation data may be necessary to achieve the limit of maximum error (stratified random sampling allows a heterogeneous population to be broken down into internally homogeneous parts). On the other hand, it is possible to have small areas of vegetation that have concentrations of particular species, which may result in higher productivity and woody plant stocking numbers. In these cases, the data should be presented, but those data can be excluded from a calculation of the statistically adequate sample size - provided the Commission is presented with field notes or explanations in order to justify their exclusion. Without adequate justification, outlier data must be included when calculating the statistically adequate sample size. Sufficient documentation should also be included with vegetation data to allow the Commission to locate the general area in case further evaluation is necessary.

2. Statistically Adequate Sample Size . Ground cover measurements will utilize the statistical equations for binomially-distributed revegetation data (Appendix A) in order to estimate a statistical adequate sample size ("sample adequacy"). Productivity and woody-plant stocking rate measurements will utilize the statistical equations for normally-distributed revegetation data (Appendix A) in order to estimate a statistically adequate sample size.

It is not acceptable to discard apparent outlier data in order to achieve a statistically adequate sample size unless acceptable information is provided to the Commission to justify their exclusion.

3. Random Point Sampling. Every point in the target evaluation area has corresponding geographic XY coordinates. These coordinates can be measured in different units (TX State Plane Coordinates, latitude and longitude, distance from a arbitrarily-chosen local landmark, etc.). An appropriate number of random pairs of values (XY coordinates) should be generated, using a random number table (Table A-1, Appendix A), a calculator with a random number generator, or any computer application that allows generation of random numbers. Some of the randomly-generated points may fall outside the evaluation area (especially with irregularly-shaped tracts of land); in those cases, an exact number of random points should be generated to replace the points that fell outside the evaluation area the first time. This process should be repeated until the required number of points have been placed within the area to be evaluated. The most convenient itinerary that passes through all of the points should then be determined. Directions should be written that will allow the person conducting the evaluation to find the

points in the field, including compass bearings and the distance from one point to the next (Raelson and McKee, 1982). An example of field directions for locating observation points is located in Table 2.

Table 2. Example of field directions for locating observation points using Random Point Sampling.

Observation No.	X, feet	Y, feet	Direction, degrees	Distance, feet
54	931	479	278 †	366 ‡
55	1525	918	324	378
56	1434	451	169	477
57	2049	172	246	675

† Azimuth bearing adjusted for magnetic declination. The bearing for each observation is the direction of travel from the preceding point.

‡ Feet can be converted to number of paces, dependent upon the person conducting the survey. The distance for each observation point corresponds to the distance of travel from the preceding point.

Example of Random Point Sampling

1) determine the limits of the area to be evaluated: the XY coordinates of the lower left hand corner of the area and the upper right hand corner of the area (the coordinates must contain the entire tract of land). Units are in feet. The XY coordinates of the corners are 42000,5300 and 43500,7200; therefore, the random values for X range between 42000 and 43500 (range of 1500) the random values for Y range between 5300 and 7200 (range of 1900);
2) generate random pairs of values. For this example, 30 points for woody plant stocking rate estimates are required; plot the first 30 combinations that fall within the evaluation area boundaries;
3) plot a most convenient itinerary that passes through all of the points, using a Computer-Aided Design (CAD) application (Figure 1 illustrates the steps through this point);
4) calculate compass bearings and distances from one point to the next
5) go to field and take measurements;

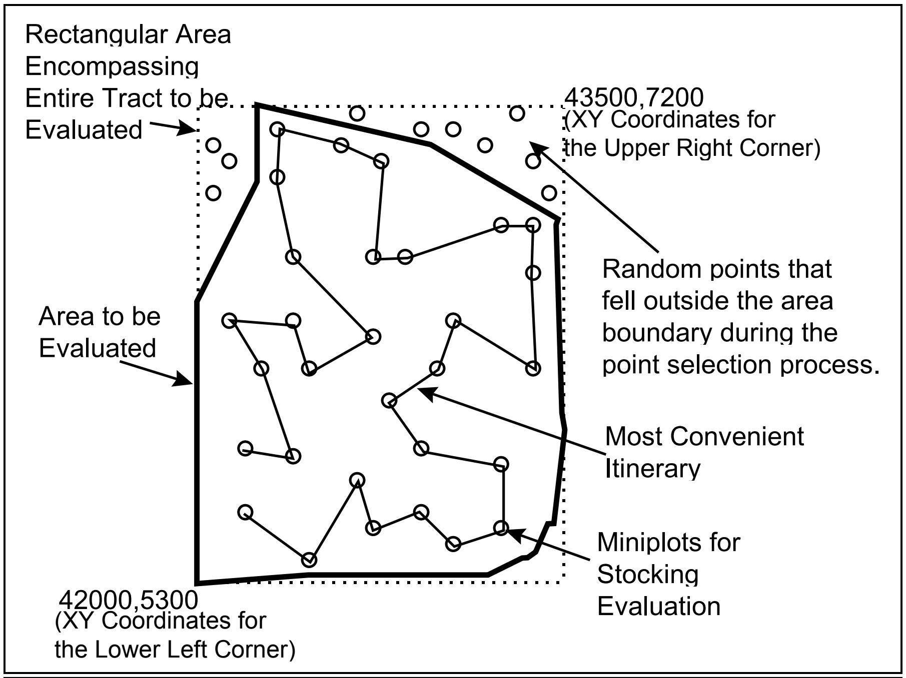

Figure 1. Example of observation point plotting and most convenient itinerary.

4. Baseline Sampling with Multiple Random Starts. This method is a modified version of systematic sampling with multiple random starts (Vogel, 1987). The placement of all transects and distances between points is randomized. This method is presented as an alternative to random point sampling, since the preceding method can be time-consuming when selecting random points and plotting them on a map. While a large number of steps are involved in this procedure, all of them are easy to implement in the field. The tools needed, at a minimum, are a ruler, a calculator, a random number table (if the calculator cannot generate random numbers), and a compass. It is also possible to generate the appropriate random numbers with a computer spreadsheet application. The steps associated with this procedure are listed as follows and illustrated in Figures 2 and 3:

1) identify the evaluation area and determine the general lengthwise orientation of the area;
2) arbitrarily identify two sides of the field as either Top and Bottom or Left and Right; (Note: for evaluation areas with a triangular shape, one of the endpoints for the baseline transect will always be at the apex of the triangle; therefore, only one baseline endpoint needs to be selected randomly);
3) measure the lengths of both sides;
4) multiply the length of each side by a random number [between 0 and 1];

5) use the products of each multiplication as the distances to determine the endpoints for the baseline;
6) the corners from which to start measuring the preceding distances are determined by whether the distances are odd or even numbers. Even numbers start at either the Top or Left, odd numbers start at either the Bottom or Right;
7) measure distances from the selected corners, following the evaluation area boundaries;
8) connect the two points on each side to create the baseline. See Figure 2 for steps 1 through 8;

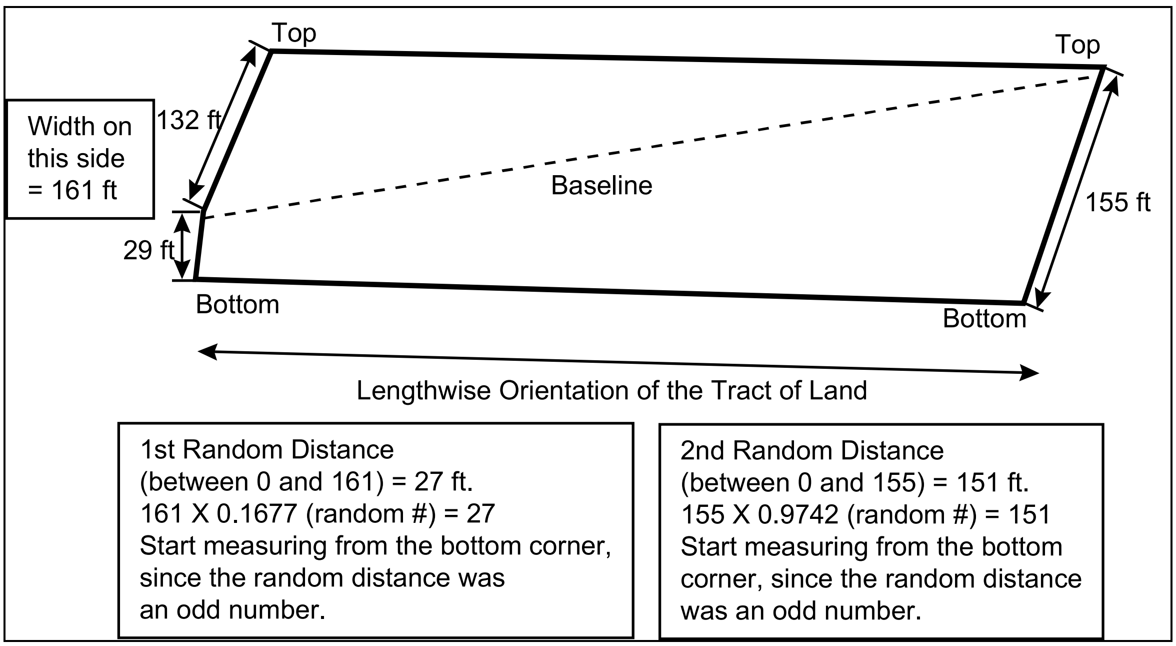

Figure 2. Baseline sampling with multiple random starts; steps 1 through 8.

9) divide baseline length by 5, the resulting number (the baseline interval) will be used to determine the distance intervals of the 5 transverse transects; (Note: if a transect [either baseline or transverse] passes through an area that is outside the evaluation area, no measurements are taken in that portion of the transect and that portion also does not count toward the total length of baseline when estimating the baseline interval lengths and observation locations);
10) multiply the baseline interval by five random numbers (between 0 and 1) to determine the relative locations of the five transverse transects;
11) pick the side of the baseline from which to start measuring the preceding distances by selecting a random number (between 0 and 1) - a number equal or less than 0.5

corresponds to either the Top or Left, random numbers greater than 0.5 correspond to either the Bottom or Right;

12) the location of the first transverse transect is equal to the first of the five random numbers determined in step 10 (measured from the starting point), the location of the second transverse transect is equal to the baseline interval distance plus the second of the five random numbers (second distance measured from the first baseline interval mark), the location of the third transverse transect is equal to the baseline interval distance times 2 plus the third of the five random numbers (third distance measured from the second baseline interval mark), the location of the fourth transverse transect is equal to the baseline interval distance times 3 plus the fourth of the five random numbers (fourth distance measured from the third baseline interval mark), and the location of the fifth transverse transect is equal to the baseline interval distance times 4 plus the fifth of the five random numbers (fifth distance measured from the fourth baseline interval mark). This step allows for random placement of transverse transects within the five interval sections of the baseline;
13) draw transverse transects that intersect the baseline perpendicularly at the previously determined locations; the transverse transects should extend to the limits of the field. See Figure 3 for steps 9 through 13;
14) placement of observation points along the baseline and the transverse transects is dependent on the following: maximum interval between points on the baseline is determined by dividing the baseline length by 15; the maximum interval between points on each transverse transects is determined by dividing the length of each transect by 8 (the distances between sample points along each transverse transect are calculated individually, since the length of each may be different) - this step will provide approximately 100 points, a greater or fewer number of points can be obtained by varying the denominators [NOTE: it is necessary to also establish a minimum interval when evaluating woody plant stocking. This minimum interval is equal to twice the diameter of the measurement plot];

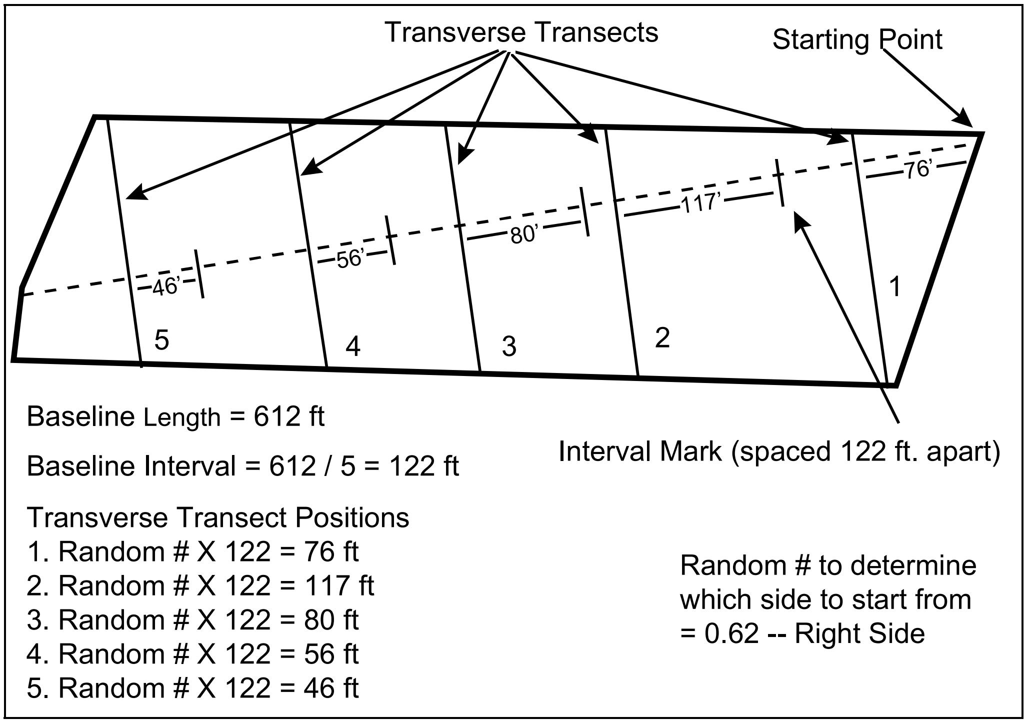

Figure 3. Baseline sampling with multiple random starts; steps 9 through 13.

15) calculate random distances between points on the baseline and the transverse transects by multiplying different random numbers by the corresponding maximum intervals;

16) repeat step 15 until the edge of the field is reached (ignore zero values, go to the next point). The starting point for the baseline is the same as in step 11, the starting points for each transect can either be at the baseline or either side of the field - it does not matter where they begin);

17) record the bearings for the baseline and the transverse transects and the corresponding random distances between observation points for each; and

18) go to field and take measurements. See Table 3 for an example of the calculations and resulting values obtained during steps 14 through 17.

Table 3. Baseline sampling with multiple random starts; steps 14 through 17.

Baseline length = 612 ft			Baseline bearing = 110°						
Maximum Interval between points = 612 / 15 = 41 ft.									
Random Baseline Points:				(Random Numbers between 0 and 41)					
13	38	39	3	1	7	36	10	28	32
4	14	2	22	13	9	33	13	35	13
1	25	2	11	41	28	38	16	40	33
			Bearing of Transverse Transects = 200° or 20°, depending on starting side						
Transect 1 Length = 158 ft				Max. Interval = 158 / 8 = 20 ft.			Random #s between 0 and 20:		
17	9	14	15	19	10	... continue until edge of field reached			
Transect 2 Length = 161 ft				Max. Interval = 161 / 8 = 20 ft.			Random #s between 0 and 20		
10	12	2	3	6	6	... continue until edge of field reached			
Transect 3 Length = 150 ft				Max. Interval = 150 / 8 = 19 ft.			Random #s between 0 and 19		
1	17	4	10	14	14	... continue until edge of field reached			
Transect 4 Length = 155 ft				Max. Interval = 155 / 8 = 19 ft.			Random #s between 0 and 19		
17	14	5	13	10	12	... continue until edge of field reached			
Transect 5 Length = 155 ft				Max. Interval = 155 / 8 = 19 ft.			Random #s between 0 and 19		
9	2	19	5	7	2	... continue until edge of field reached			

B. Adjusting for Field Conditions when Conducting Vegetation Surveys

Non-vegetated structures such as permanent roads, permanent ponds, rip-rap areas, and rock piles and brush piles created for wildlife are not included as part of the revegetation analyses; therefore, whenever an observation point falls on such a structure, disregard that measurement and go to the next observation point. Habitat features in grazingland and pastureland must be included in ground cover and productivity measurements. When the edge of the measured field is intercepted before the next observation location is reached, do not take any more measurements for that particular transect.

Slopes under 25 percent should not influence on-the-ground measurement intervals enough to warrant modifying the distances between observation points; therefore, it is not necessary to make adjustments when traversing sloping terrain.

Individual areas to be surveyed (i.e.: sample units) must be under the same land use and management and be comprised of the same vegetation type. Areas to be surveyed individually must be internally homogeneous (contain similar characteristics); otherwise, the evaluation area must be stratified into separate sample units. The principal criteria used to identify homogeneous evaluation areas are same land use, similar vegetation population, and comparable management.

C. Ground Cover

Ground cover measurements are required for all land uses, except for cropland after row crops have been planted. Of the various ground cover measurements traditionally used, the point intercept method (sometimes called point frequency), using a pair of crosshairs, has been found to be the most accurate and reliable (Raelson and McKee, 1982), and for this reason, it is the recommended method for determining ground cover. This section discusses the use of the point intercept method with a crosswire sighting device to determine ground cover. The theoretical basis of the method and practical considerations are summarized in this section.

1. Point Intercept - Theory. The theoretical basis of the point intercept method of measuring vegetative ground cover has been explained by Raelson and McKee (1982) as follows. A sample area (quadrat) has a small size which may either be completely covered by the projection of the areal parts of the vegetation, incompletely covered, or not covered at all. As the size of the sample area is reduced, it becomes more likely that it is either completely covered or not covered at all, until when it is infinitely small that it is always either completely covered or not covered. As the sample area decreases in size, the proportion of the total number of sample areas that are either partially or completely covered approaches more nearly to the value of the cover. At the limit, when the sample area becomes a point, the proportion of an infinitely large number of points that is covered by vegetation equals the vegetative cover.

2. Point Intercept - Field Sampling Procedures. A sighting tube, that aligns or superpositions two reference points (crosshairs), is used to determine the ground cover (Figure 4). The intersecting crosshairs should be as thin as possible to define the point of measurement without significant bias. The sighting device can be constructed out of a variety of materials. The sighting tube should be mounted on the side of a short pole that is pointed at one end, allowing it to be forced into the ground and remain free-standing. Some designs include a leveling device and compass attached to the pole.

Sequence of Events:

1) obtain appropriately-scaled map or aerial orthophotograph that depicts the area(s) that need to be evaluated;

2) select method of obtaining observation points - either random point sampling or baseline sampling with multiple random starts;

3) select and plot 100 observation points. Approximately 100 observation points will be obtained with the baseline method, the actual number will depend on the random numbers that were generated;
4) prepare field document that identifies the directions and distances between the observation points;
5) initially inspect the area to be evaluated to ascertain that it is internally homogeneous;

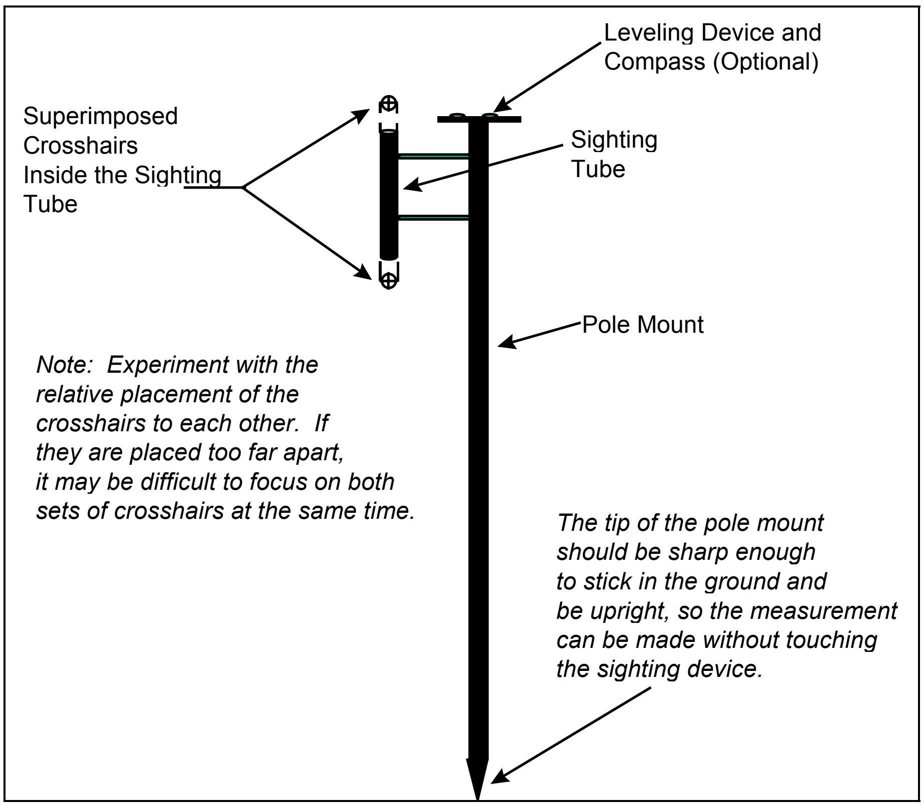

Figure 4. Sighting device with paired crosshairs for making point-intercept ground cover observations.

6) begin ground cover survey; locate the survey starting point by using clearly-defined benchmarks and proceed to the first observation point, measuring or pacing the correct distance and using a compass for the correct bearing;
7) after reaching the first observation point, extend your arm to one direction and force the sighting device into the ground. There must be no subjectivity in placing the device. Always place the device in the same direction from your body in order to make the procedure as mechanical and consistent as possible. Once the device is

free-standing, **do not** move it until after the measurement is taken;

8) once the sighting device is positioned, look through the sighting tube and move your eye, if necessary, to align the two crosshairs. Record whether the point created by the intersecting crosshairs intercepts any vegetation (record the first object that is intercepted). There are several outcomes at this point: a hit (intercepts approved vegetation, either alive or dead, or litter), a miss (intercepts bare ground or unapproved vegetation), or rock fragments. Observation points that include rock fragments are identified and recorded but not used when calculating the overall ground cover. The points that are classified as "hits" should identify what was intercepted: a plant species or litter;
9) other vegetation parameters, such as productivity or woody-plant stocking, can be measured at this point, after the ground cover is recorded; and
10) Proceed to the next observation point, and repeat the measurement process. The number of points that intercepted permit-approved vegetation (and up to 15% litter) is divided by the total observations that were taken that did not include rock fragments, to arrive at a percent ground cover value.

<u>3. Other Methodologies for Measuring Ground Cover</u> There are several methods for measuring ground cover other than the point intercept method. If a permittee proposes to use an alternative ground cover measurement procedure, it must be approved by the Commission prior to use and must be included in the approved regulatory program. Any proposed alternative procedures must include corresponding statistical equations and must provide data that include a 90% statistical confidence interval (one-sided test with a 0.10 alpha error).

D. Productivity

The method of measurement of productivity is dependent on the land use and the established vegetation. The primary goals of productivity evaluation are that the production estimates be representative of the area and vegetation being evaluated and that the vegetative components being measured are compatible with established agricultural commodities.

Productivity (yields from forage, food, or fiber crops) can be evaluated via hand-harvesting or with mechanized agricultural implements. Productivity measurements **must be obtained during the growing season** of the primary vegetation species. Productivity is estimated from only the current season's growth. There are two methods that can be used for evaluation of either herbaceous species and food or fiber crops: harvesting of plots or whole-field harvests. The use of double-sampling and grazing methods are restricted to herbaceous species being used for pasture or grazingland.

1. Agricultural Commodity Being Evaluated. Production can be based either on the total above-ground plant growth during a certain period of time or the yield of a specified part of the plant (such as grain, fruit, roots, hay, or fiber). Above-ground plant material (biomass) yields for reclaimed areas are only compared to biomass yields of reference areas, unless a technical standard has been approved that involves total biomass values. Usually, pasture and grazingland production is based on technical standards where all of the above-ground biomass is not normally harvested. Reclaimed areas must be harvested or sampled in the same manner (i.e.: the same vegetative components - grain, hay, etc.) as the areas upon which technical standards are based (Vogel, 1987).

2. Factors to Consider When Evaluating Productivity. There are two components that will potentially influence the end results of production yields: time of harvest and moisture content.

Time of Harvest. Herbaceous species should be harvested at the times appropriate to the plant species (i.e.: cool-season species should be sampled in the winter or spring; warm-season species should be sampled in the summer or fall). Sampling should be timed to coincide with seed ripeness or the mature stage of the target vegetative species. Plant communities that are comprised of both cool- and warm-season species should be sampled when the overall plant community production is at a peak. It may also be acceptable to sample at two different times if the occurrences of peak production for the major species differ by more than 3 months. Multiple harvests are also appropriate in more intensive forage production operations. Additionally, all harvests (either single or multiple) should reflect the amount of biomass produced in one year. If an area has not had herbaceous biomass removed (i.e. mowing, baling, grazing) since the last sampling, then sampling must not be conducted until the vegetation is removed and regrowth has taken place.

Moisture Content. The moisture content of harvested herbaceous biomass and other vegetative/grain components must be standardized, in order to eliminate weight variations due to moisture content. Typically, herbaceous (forage) biomass weights are standardized by oven-drying at 60° C for twenty-four hours or until the weight stabilizes. Vegetation production that is compared to technical standards should be measured on the same dry-weight basis as the standard. Grain/beans from row crops should be evaluated for moisture content and weights should be adjusted to the appropriate moisture content for that agricultural commodity. The determination that a statistically adequate sample size was obtained is performed on standardized or corrected dry weights.

Immediately after the grain or beans are harvested and collected, they must be weighed to three significant digits and then have moisture content measured. Moisture content must be determined using a properly calibrated, standard agricultural grain moisture tester. The correction of the measured grain/bean weights to appropriate moisture contents is performed as follows:

$$CGW = \frac{(100 - MM)}{(100 - SMP)} \times GW, \quad \text{where:}$$

CGW =	Corrected grain (or bean) weight
SMP =	Standard moisture percentage (appropriate percent moisture for that particular agricultural commodity
MM =	Measured moisture
GW =	Grain or bean weight

3. Whole-Field Harvesting. The total production from a hayed or harvested area is obtained by weighing the entire yields of the agricultural commodity. The Commission shall be notified fifteen (15) to (30) days prior to the harvest. The Commission may require that an inspector be on site during the harvest activity. The baling of herbaceous vegetation requires that the forage crop be

harvested following sound agronomic practices (i.e.: the proper agronomic haying practices were utilized for that particular species, the cut forage was allowed to field-dry, and baling did not occur at forage moisture contents above 25%). Moisture contents for grains/beans must be adjusted to the accepted values for each agricultural commodity. Weights must be obtained with a calibrated scale. Statistical calculations are not needed for whole-field harvest data. The foreign material content of the grain/beans shall be determined by a licensed grain dealer and the weight shall be shrunk to marketable condition weight with a foreign material allowance of one percent (1%). There will be no allowances for harvest and handling losses.

4. Hay Bale Weights . Average bale weights must be estimated when only a portion of the total bales produced will be weighed to represent the total production of an area. Average bale weights can be estimated by weighing a number of individual hay bales or truckloads of hay bales. Selected hay bales will be representative of the area being evaluated.

Individual Hay Bales. At least 15 random bales per individual area (sample unit) must be weighed The final number of hay bales weighed should not exceed 30 and will depend on hay bale variability. Sample adequacy must be met. Multiply the number of hay bales per area by the average bale weight to obtain total production for that area. A 90% confidence interval can be obtained from the individual bale weight calculations.

Truckloads of Hay Bales. At least three truckloads from each 100 acres will be weighed (the minimum of 15 samples, as required for other productivity data, will not be used in this case). A sample will consist of the average bale weight truckload. Each truckload should have at least 3 round hay bales or 20 square hay bales. A sample will consist of the average hay bale weight/truckload. A statistically adequate sample size must be obtained. Multiply the number of hay bales per area by the average bale weight to obtain total production for that area. A 90% confidence interval can be obtained from the average bale weight calculations.

5. Harvest of Plots. The harvesting of plots instead of the whole area is an acceptable alternative, as long as the yields of the plots are representative of the overall production. Yield estimates obtained from plots can be subject to large sampling errors; therefore, it is important to carefully follow the appropriate sampling protocols.

Information to Collect. Ancillary information related to the evaluated area should be collected in order to properly appraise the production data. Table 4 summarizes the additional information that should be obtained.

Plot Size. The size of plots can vary, depending on the agricultural commodity being evaluated. Herbaceous species are commonly measured with circular, square, or rectangular quadrats or plots. Quadrat size should be determined by the vegetation type (Table 5). Selection of quadrat size must be appropriate for the vegetation community being evaluated, as smaller quadrats may result in more variable measurements. Row crops can be evaluated by harvesting plots that are 1/1000-acre in size. It will be necessary to determine the row-feet in 1/1000-acre with the following formula (Texas Agricultural Extension Service, 1986):

$$\text{Row-feet in 1/1000-acre} = \frac{522.72}{\text{Row Width (in.)}} \quad \text{Example for 27-in. row width} = \frac{522.72}{\text{27 in.}} = \text{19 ft. 4 in.}$$

Table 4. Additional information to accompany productivity data.

Herbaceous Vegetation	Row Crops
Plant species composition (relative proportions in mixed stands)	Cultivar planted
Date of last shredding/mowing/or prescribed burning	Planting rate
Plot size	Fertilization (in lbs/acre of N-P_2O_5-K_20).
Harvest date	Plot size
Harvest method	Harvest date
Harvest height	Harvest method
Growing season rainfall	Growing season rainfall
Person collecting data	Person collecting data

Table 5. Minimum quadrat sizes for sampling herbaceous production (from Vogel, 1987).

Vegetation Type	Metric Measure (m^2)	English Measure (ft^2)
Dense† tall-grass prairie and pastures	0.25 - 0.75	2.7 - 8.1
Sparse‡ tall-grass prairie and pastures	0.50 - 1.50	5.4 - 16
Woodlands - dense understory	0.75 - 1.50	8.1 - 16
Woodlands - sparse understory	1.00 - 2.50	10.8 - 26.8
Dense mid-grass prairie	0.25 - 0.75	2.7 - 8.1
Sparse mid-grass prairie	0.50 - 1.50	5.4 - 16

† More than 50% aerial cover.

‡ Less than 50% aerial cover.

Harvest Procedure. Harvest specifications for food and fiber crops will depend on the agricultural commodities involved. The harvest of grain/beans will be done in a uniform fashion for each sample unit. Clipping of herbaceous vegetation can be done at ground level or as close to it as possible when reclaimed areas are being compared to reference areas or grazing levels are being verified. The height of clipping for comparison to technical standards will duplicate the height normally obtained with haying equipment. Litter and other attached non-green matter is not included in the sample. Only permit-approved species for the appropriate land use are included in the sample; all other species must be discarded from the sample. Only vegetative portions of permit-approved plants rooted within the boundaries of the plot are included in the sample. Therefore, even portions of the foliage of the plants that overhang the plot, and that are rooted within the plot, are sampled. Conversely, parts of plants that overhang the plot, but are not rooted in it, are not included in the sample. Only the portion of bunchgrasses that is rooted within the plot is sampled (in cases where the plot boundary divides the base of the bunchgrass). Store the harvested material (grain/beans, forage) in a suitable container. Permanently mark on each container the field or plot number and sample number. Non-forage harvested materials should be processed (i.e., thrashed) in order to obtain grain/bean weights.

Sample Number. The number of plots needed to characterize the entire field will depend on the variability of the vegetation. Approximately 30 plots should be randomly-placed, regardless of the size of the area to be evaluated. Sampling can begin on a smaller proportion of the 30 plots if initial reconnaissance of the area indicates that the ground cover appears to be fairly uniform over the entire area. If the area is relatively uniform, begin by collecting samples from 15 out of the 30 plots (i.e.: collect samples from every other observation point). The undried weights of herbaceous vegetation or any other target vegetative component may be used to determine if a statistically adequate sample size has been obtained (a function of the field's variability). However, final determination of a statistically adequate sample size will be made with the oven-dry or moisture-corrected weights. The number of samples required is calculated following procedures listed in Appendix A.

No further sampling will be required if the statistically adequate sample size (N) is calculated to be equal or less than 15 (the number of samples initially taken). However, if N is greater than 15, the number of additional measurements required will equal N minus 15 (N - 15). A new value of N is calculated each time additional measurements are made to ensure that a sufficient sample size is obtained. For example, if N is determined to be 19, then four additional samples must be collected from the remaining 15 locations that were not sampled during the initial round. To select the four additional sampling locations, divide the remaining fifteen observations by four (15 ÷ 4 = 4). Therefore, samples will be collected from every fourth observation point, excluding those points that were sampled during the first round. Continue this procedure until the actual number of measurements taken produces a statistically adequate sample size.

Determination of Moisture Content. There are two options available when measuring forage production from plots: 1) oven-dry the entire volume of forage or 2) determine moisture content from subsamples. In cases where moisture content will be measured, a representative sample of the herbaceous vegetation should be collected from each sampling location for determination of oven-dry weight. At least 100 grams from each sampling location should be used. For herbaceous vegetation, a proportional representation of species, stems, stalks, and leaves, should be sent to a lab for moisture testing. Each observation point should have its own subsample for moisture determination. Place the subsamples in polyethylene bags labeled with the site name, permit number, observation point number, and date. The oven-dry weight of herbaceous vegetation must be adjusted to a 15% moisture content ("hay equivalence") before it is converted to production of forage per acre. Multiply the oven dry weight (in tons/acre) by 1.176 to obtain tons of hay equivalence per acre. Grain from row crops should be evaluated for moisture content and weights should be adjusted to the appropriate moisture content for that agricultural commodity.

6. Double-Sampling Method. The double-sampling method can be used to reduce the time required to measure productivity (Bonham et al., 1980). This technique uses statistical regression to estimate one vegetation parameter (actual biomass weight) by using measurements taken from different, but correlated, vegetation characteristics (i.e.: visual estimate of productivity). The general form of the regression equation is:

$$\hat{y} = a + bx$$

where $\hat{y}$ is the predicted value of productivity, *a* is a constant, *b* is the slope of the regression line, and *x* is the measured correlated vegetation characteristic used to predict *y* (actual productivity). The double-sampling method involves two observers. One observer makes an ocular estimate of the vegetation production in an appropriately-sized quadrat (dependent on vegetation type and density) while the second observer clips the biomass from the same quadrat (thereby obtaining an estimate of the vegetation production).

This procedure requires training in ocular estimation of productivity prior to actually collecting data, since the observers **do not** compare production estimates during the actual data collection period. Estimate comparisons (i.e.: ocular calibration) should be carried out during a period of time separate from the actual sampling. A ratio of clipped estimates to ocular estimates (one clipped estimate for every 10 ocular estimates) is maintained during the entire time the data is collected. The quadrats where both an ocular and clipped estimate are obtained are used to develop a regression equation that is used to adjust the other ocular estimates of production.

The double-sampling technique's effectiveness is dependent on the precision of the ocular estimation procedure. The ocular estimates should be made by the same individual and the procedure must not be biased by reviewing the estimates during the sampling period. Likewise, the clipping estimates must be obtained by maintaining a consistent clipping height that is appropriate to the vegetation type (follow instructions included in section addressing *Harvest of Plots*). Excessive variability may result if consistency is not maintained, and this variability will reduce the effectiveness of the double-sampling procedure.

A 90% statistical confidence can be obtained from the regression equation; however, double-sampling method results will not be accepted if the following conditions are not met: 1) the regression coefficient (R^2) of the regression is equal to or greater than 0.80 and 2) the maximum error relative to the mean is equal to or less than 10% (calculated using the equation below):

$$\frac{\left(\text{Confidence Interval}/2\right)}{\bar{x}\ (\text{mean})} \times 100 = \text{Maximum error relative to the mean}$$

<u>7. Grazing Method.</u> The conversion of animal units (AU) to a weight of vegetation biomass for a given area can be used to estimate productivity in grazingland and pasture land uses instead of whole-field or plot harvesting. The animal numbers should be maintained in a manner that allows grazing of the current year's forage production without damaging future forage growth and quality (Troxel and White, 1996). In general, sod-forming grasses can usually be grazed to lower heights than bunch grasses. The recommended plant residue levels are found in Table 6.

Table 6. Minimum plant residue levels and stubble heights to sustain production (from McGinty, 1996).

Range Type	Plant Residue Level, lbs/acre	Stubble Height, inches
Short grass	300 - 500	1.5
Mid-grass	750 - 1000	4 - 6
Tall grass	1200 - 1500	8 - 10

Units to measure grazing will be animal unit months (AUM), the amount of forage required by an animal unit for one month. Table 7 contains a guide to animal-unit equivalents (USDA-SCS, 1976). The following summarizes the assumptions that are made in estimating the amount of forage production needed (1,560 lbs) for an AUM (all values obtained from the USDA-SCS, 1976); including sufficient forage left to protect the soil:

- 1 AU (1000 lbs) consumes 26 lbs dry weight of forage/day
- 26 lbs dry weight X 30 days = 780 lbs. per month
- 1 AUM = 780 lbs. forage consumed
    - Assume a 50% utilization efficiency compared to hay production (approximately 50% forage lost through trampling, etc.)
    - Therefore, the amount of production needed is 1,560 lbs (780/.50)
    - Additionally, the appropriate amount of plant residue (see Table 6) should remain at the end of grazing. This plant residue level must be verified

through clipped plots (see Section IV.D.5). A statistically adequate sample size must be obtained.

Table 7. Animal-unit equivalents (USDA-SCS, 1976).

Kinds and Classes of Animals	Animal-Unit Equivalent
Cow, dry	1.00
Cow, with calf	1.00
Bull, mature	1.25
Cattle, 1 year of age	0.60
Cattle, 2 years of age	0.80

Stocking rates will be verified by including a signed affidavit from the party managing the grazing of a given area (the affidavit must identify the time period covered and the class of livestock involved).

E. Woody Plant Stocking

Randomly-selected measurement locations are required for conducting woody plant stocking evaluations. Observation points should not be located within 20 feet of the edge of the stocked area. Observation points for woody plant counts can also be used for measuring ground cover. Woody plants counted for success determination must be alive and healthy and in place for two growing seasons.

Miniplots, usually circular in shape, are used to determine stocking rates. The number of eligible stems contained within the miniplot are used to estimate woody plant stocking rates. The miniplot size used should be reported along with the data. Please note that it is necessary to establish a minimum interval between observation points when evaluating woody plant stocking (to prevent miniplots from overlapping). This minimum interval is equal to twice the diameter of the measurement plot.

Sample Number. The number of plots needed to characterize the evaluation area will depend on the variability of the vegetation. Approximately 30 plots should be randomly-placed, regardless of the size of the area to be evaluated. Sampling can begin on a smaller proportion of the 30 plots if initial reconnaissance of the area indicates that the ground cover appears to be fairly uniform over the entire area. If the area is relatively uniform, begin by collecting samples from 15 out of the 30 plots (i.e.: collect samples from every other observation point). The number of samples required is calculated following procedures listed in Appendix A.

No further sampling will be required if the statistically adequate sample size (N) is calculated to be equal or less than 15 (the number of samples initially taken). However, if N is greater than 15, the number of additional measurements required will equal N minus 15 (N - 15). A new value of N is calculated each time additional measurements are made to ensure that a sufficient sample size is obtained. For example, if N is determined to be 19, then four additional samples must be collected from the remaining 15 locations that were not sampled during the initial round. To select the four additional sampling locations, divide the remaining fifteen observations by four (15 ÷ 4 = 4). Therefore, samples will be collected from every fourth observation point, excluding those points that were sampled during the first round. Continue this procedure until the actual number of measurements produces a statistically adequate sample size.

F. Selection and Management of Reference Areas

The permittee will work closely with the Commission staff to select and develop a suitable reference area, in cases where a reference area is to be used in determining revegetation success. Criteria for selecting a suitable reference area have been described by Chambers and Brown (1983) and the U.S. Dept. of the Interior (1981). The selection of the reference area will be dependent upon 1). the proposed land use for the reclaimed area and 2). the approved revegetation plan for each individual mine. The following is the definition of a reference area (§12.3 of the TCMR):

> A land unit maintained under appropriate management for the purpose of measuring vegetation ground cover, productivity and plant species diversity that are produced naturally or by crop production methods approved by the Commission. Reference areas must be representative of geology, soil, slope, and vegetation in the permit area.

When properly selected and managed, reference areas serve as standards of comparison to assess whether or not revegetation of the reclaimed areas has been successful.

Reference areas are unmined land units that are maintained under appropriate management for the purpose of measuring vegetation ground cover, productivity, and other parameters, such as plant species diversity, that are produced naturally or by agricultural production methods that are approved by the Commission. The following list includes criteria for comparing revegetated mined areas and reference areas (from Vogel, 1987):

- site factors such as elevation, precipitation, slope, and aspect should be similar on both areas;
- both areas are composed of the same plant life-forms and seasonal varieties of vegetation
- management of the reference area during the revegetation phase should be comparable with that proposed for the revegetated, mined area; and
- performance of a revegetated, mined area should be realistically comparable to the reference area.

At least one reference area per type of inventory unit (i.e.: vegetation type, range site, etc.) is desired (Vogel, 1987). It is not essential that the reference area be immediately adjacent to the mined, revegetated area; however, the two areas should be close enough to each other in order to prevent differences in rainfall distribution patterns.

Section V. Revegetation Success Standards

The revegetation success standards for the corresponding vegetation parameters will be listed by the land use type. Nine general types of land use are included: grazingland, pastureland, cropland, forestry, fish and wildlife habitat, undeveloped land, industrial/commercial, residential, and recreation. See Appendix B for a table summarizing the revegetation success standards.

A. Grazingland and Pastureland

Two vegetation parameters are measured for grazingland and pasture: ground cover and productivity.

1. Ground Cover. The ground cover values of mined, revegetated areas are compared either to the ground cover of an approved reference area or to approved technical standards. The revegetation success standard when reference areas are used is that the ground cover of the revegetated grazingland or pastureland must be 90% of the reference area with a 90% statistical confidence. The approved technical standards for grazingland and pastures are dependent upon the moisture regime (5- or 10-year ERP areas) and the dominant plant species.

Use of Reference Areas. The following steps should be followed when reference areas are used as a measure for revegetation success.

Measurements: 1) Measure and record the ground cover value for the reference area; and 2) Measure and record ground cover value for reclaimed area, only permit-approved permanent species (including any additional species found in the reference area) will count toward the ground cover value.

Statistical Comparison: First compare the reclaimed area ground cover estimate to 90% of the reference area ground cover (also called the lowest acceptable value) The lowest acceptable value based on the reference area is 90% of the ground cover value obtained (i.e.: 90% of a ground cover value of 93% would be 83.7%). If the reclaimed area ground cover is equal to or greater than the lowest acceptable value, there is no need to perform a hypothesis test (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area ground cover is less than the lowest acceptable value, perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, binomially-distributed data). An example of calculations is found in Appendix C.

Use of Technical Standards*.* The following steps should be followed when technical standards are used as a measure for revegetation success.

Moisture Regime and Grass Type. The technical standards will be affected by amount of average annual precipitation and the grass type. For areas with an average annual precipitation greater than 26 inches, the following technical standards will be used: 1) Sod-forming grasses: ground cover standard is 95%; 2) Bunch grass mixtures: ground cover standard is 90%. For areas with an average annual precipitation less than or equal to 26 inches, the following technical standards will be used: 1) Sod-forming grasses: ground cover standard is 90%; 2) Bunch grass mixtures: ground cover standard is 80%.

Statistical Comparison: First compare the reclaimed area ground cover estimate to 90% of the appropriate ground cover standard (also called the lowest acceptable value). The lowest acceptable value is obtained by multiplying the appropriate technical standard (based on the moisture regime and vegetation type) by 0.9 (i.e.: 90% X 0.9 = 81%) If the reclaimed area ground cover is equal to or greater than the lowest acceptable value, there is no need to calculate a confidence interval (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area ground cover is less than the lowest acceptable value, calculate a one-sided 90% confidence interval (see Appendix A, binomially-distributed data). Examples of calculations are found in Appendix C.

Species Composition. Ground cover measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as ground cover observations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

2. Productivity. The productivity of mined, revegetated areas is compared either to the productivity of an approved reference area or to an approved technical standard. The revegetation success standard, when reference areas are used, is that the productivity of the revegetated grazingland or pastureland must be 90% of the reference area with a 90% statistical confidence. The approved technical standards for grazingland and pastures are currently developed by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), in response to mining industry requests for permit-specific standards. The following are general guidelines for collecting productivity data for reference and reclaimed areas for grazingland and pastureland evaluations: 1) Whole-field harvesting is appropriate for grazingland or pastureland harvested for hay. 2) The harvest of plots is appropriate for all grazingland and pastureland. The clipping height is dependent upon whether the field will be hayed or grazed. The timing and frequency of cuttings during a growing season should correspond to the approved land use and planned stocking rates (if area is to be utilized by cattle). 3) Double-sampling method also requires proper control of cutting height. 4) Use of the grazing method is dependent on identification of the animal species (with corresponding gender and age), stocking rate, range management plan(s), and verification that proper amount of plant residue is left after grazing is completed.

Use of Reference Areas. Productivity comparisons between reference and reclamation areas should be performed using similarly-obtained data. Both areas should be harvested as close to the same time as possible, using the same harvesting methods.

Measurements: The productivity of the reference area must first be determined, followed by estimation of reclaimed area productivity.

Statistical Comparison: Determine the lowest acceptable value for the productivity of the reference area, by calculating 90% of the reference area productivity value (i.e.: 90% of 2,300 lbs/ac would be 2,070 lbs/ac). Use the actual yield for the reclaimed area productivity. Then, compare the reclaimed area productivity to the lowest acceptable value for the reference area. If the reclaimed area productivity is equal to or greater than the lowest acceptable value, there is no need to perform a hypothesis test (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, perform the following hypothesis test, using a one-sided 90% confidence interval. The hypothesis test is based on a two-sample comparison for small samples (see

Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

Use of Technical Standards. Many of the mining companies in Texas have elected to use technical production standards, instead of reference areas to demonstrate grazingland and pastureland productivity success on reclaimed areas. Site-specific productivity standards for grazingland and pastureland production are currently developed by the USDA-NRCS, in response to mining industry requests for these standards. The USDA-NRCS has developed a stand-alone document which specifies technical production standards and is included in the permit application for each mine. Therefore, the technical production standards are site-specific for each mine with respect to rainfall, species/cultivar produced, soil mapping unit, and fertilization. The technical productivity standards developed for each mine are subject to review and hearing procedures during the permit review and approval process. The current approach of developing technical productivity standards allows for flexibility in developing new and improved standards as new species/cultivars are released, land uses are changed, or additional soils are identified. The updated information is incorporated in the mining permit through the regulatory permitting process, thus ensuring review and approval. The methodology used by the USDA-NRCS to develop technical productivity standards is outlined by the following steps (example found in Attachment 1):

- all soil mapping units in the area to be disturbed are identified;
- proposed land use and species/cultivars to be planted are identified;
- yield curves are developed by using research data, such as field trials, and other factors, such as rainfall and fertilizer application rates;
- the relative productivity of each species on each soil mapping unit is developed by using the normal rainfall recorded at the nearest recording station;
- the productivity standard (PS) is then computed as follows: PS (tons/acre/year) = (GSR/RR)(RP), where: GSR is growing season rainfall; RR is required rainfall (inches) per ton of forage; and RP is relative productivity.
- where harvesting is by grazing, the productivity standard is reported in animal unit months (AUM).

<u>Statistical Comparison</u>: Compare the productivity of the reclaimed area, with a 90% confidence interval, to the appropriate technical standard. If the reclaimed area productivity is equal to or greater than the technical standard, there is no need to calculate a one-sided 90% confidence interval (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the technical standard, a confidence interval must

be calculated (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

B. Cropland

Two vegetation parameters are measured for cropland: ground cover and productivity. This land use will be divided into two sections, depending on whether or not restored prime farmland soils are involved.

1. Ground Cover of Non-Prime Farmland Soils Adequate ground cover to control erosion is required until crop production begins (based on Revised Universal Soil Loss Equation).

2. Productivity of Non-Prime Farmland Soils The productivity of mined, revegetated areas where non-prime farmland soils were involved is compared either to the productivity of an approved reference area or to approved technical standards.

Use of Reference Areas: Productivity comparisons between the reference and reclamation areas must be performed using similarly-obtained data. Both areas should be harvested as close to the same time as possible, using the same harvesting methods.

Measurements: First, determine the productivity for the reference area, then determine productivity for reclaimed area.

Statistical Comparison: Determine the lowest acceptable value for the productivity of the reference area, by calculating 90% of the yield obtained from the reference area (i.e.: 90% of 2,300 lbs/ac would be 2,070 lbs/ac). Use the actual yield for the reclaimed area productivity. Then, compare the reclaimed area productivity to the lowest acceptable value for the reference area. If the reclaimed area productivity is equal to or greater than the lowest acceptable value, there is no need to perform a hypothesis test (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, normally-distributed data). An example of the calculations is found in Appendix C.

Use of Technical Standards. The technical success standards for the proposed crops will be determined by the USDA-NRCS, at the request of the mine operator or landowner. Therefore, the technical success standards will be permit-specific and will be developed by using data on the expected individual crop productivity for the particular county and soil mapping unit, as published in the USDA-NRCS Field Office Technical Guides. The productivity standards developed by using this approach will be subject to review and approval by the Commission during the permit review and approval process. For bond release in areas receiving more than 26 inches of precipitation (5-year responsibility period), the total field harvest of the crop for any two years (except the first year) will be compared to the approved productivity standard specifically developed for the particular crop and a particular growing season. In areas receiving 26 inches of precipitation or less (10-year responsibility period) the production standards must be met in at least the last 2 consecutive years of the responsibility period.

Statistical Comparison: First compare the productivity of the reclaimed area to 90% of the appropriate technical standard (also called the lowest acceptable value. The lowest acceptable value is obtained by multiplying the technical standard by 0.9 (i.e. 1200 lbs/acre X 0.9 = 1080 lbs/acre). If the reclaimed productivity is equal to or greater than the lowest acceptable value, there is no need to calculate a confidence interval (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, normally-distributed data. An example of the calculations can be found in Appendix C.

3. Ground Cover of Restored Prime Farmland Soils Adequate ground cover to control erosion is required until crop production begins (based on Revised Universal Soil Loss Equation).

4. Productivity for Restored Prime Farmland Soils. Prime farmland productivity will be restored in accordance with provisions specified in §12.625 (Texas Coal Mining Regulations). Productivity of restored prime farmlands will be returned to equivalent levels of crop yields as non-mined land of the same soil type in the surrounding area under equivalent management practices. Measurement of crop productivity will be initiated within 10 years after completion of soil replacement. The measurement period for determining average annual crop production (yield) shall be a minimum of three crop years prior to bond release. Crop production may be measured in any of the ERP years except the first, in areas receiving more than 26 inches of precipitation. For areas receiving 26 inches of precipitation, or less, the crop production standards must be met in at least the last two consecutive years of the ERP.

The reference crops on which restoration of soil productivity is proven shall be selected from the crops most commonly produced on the surrounding prime farmland. Only two of the three required crop years may involve forage crops. Where row crops are the dominant crop grown on prime farmland in the area, the row crop requiring the greatest rooting depth shall be chosen as one of the reference crops. The specific reference crops to be used will be specified by the permittee in the mining permit application. Selection of the reference crops must be accomplished through consultation with the USDA-NRCS, with documentation of such included in the permit application.

Use of Reference Areas. Reference areas are not applicable where restored prime farmland soils are involved.

Use of Technical Standards. Productivity of crops grown on reclaimed restored prime farmland soils will be measured by using the crop yield of a reference crop produced on all or a portion of the reclaimed prime farmland area. The reference crop yields for a given crop season will be compared to average yields for specific prime farmland soil series. These average yields are obtained from the USDA-NRCS' National Soil Information System (NASIS) database, which contains information linking soil series and slope phase, land capability, and crop yields. Average yields for the non-mined prime farmland soil series must be obtained through consultation with the USDA-NRCS and included in the permit application.

Statistical Comparison: Restoration of soil productivity shall be considered achieved when the average yield during the measurement period equals or exceeds the average yield of the reference crop established for the same period for non-mined soils of the same or similar texture or slope phase of the soil series in the surrounding area under equivalent management practices. Yields will be determined through whole-field or plot harvesting (Section IV.D). If the reclaimed area productivity is less than the average yield of the reference crop, perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

C. Forestry

The forestry land use category is related to land used or managed for the long-term production of wood, wood fiber, or wood-derived products (i.e.: commercial forest land). Two vegetation parameters are measured for forestry: ground cover and woody-plant stocking rates.

1. Ground Cover. The ground cover values of mined, revegetated forestry areas are compared either to the ground cover of an approved reference area or to approved technical standards. The ground cover of the reclaimed forest must be within 90% of the success standard with a 90% statistical confidence.

Use of Reference Areas. The ground cover of the reclaimed forest area must be within 90% of the ground cover of the reference area, with a 90% confidence interval.

Measurements: 1) Measure and record the ground cover value for the reference; and 2) Measure and record the ground cover value for reclaimed area; only permit-approved permanent species (including any additional species found in the reference area) will count toward the ground cover.

Statistical Comparison: First compare the reclaimed area ground cover estimate to 90% of the reference area cover (also called the lowest acceptable value). The lowest acceptable value for the reference area is 90% of the ground cover value obtained. (i.e.: 90% of a ground cover value of 83% would be 74.7%). If the reclaimed area ground cover is equal to or greater than the lowest acceptable value, there is no need to perform a hypothesis test (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area ground cover is less than the lowest acceptable value, perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, binomially-distributed data). An example of the calculations is found in Appendix C.

Use of Technical Standard. The technical standard where woody plants are used must be equal to or greater than 78% ground cover.

Statistical Comparison: First compare the reclaimed area ground cover estimate to 90% of the ground cover standard (also called the lowest acceptable value). The lowest acceptable value is obtained by multiplying the technical standard by 0.9 (i.e.: 78% X 0.9 = 70%). If the reclaimed area ground cover is equal to or greater than the lowest acceptable value, there is no need to perform a hypothesis test (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area ground cover is less than the lowest acceptable value, perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, binomially-distributed data). An example of the calculations is found in Appendix C

Species Composition. Ground cover measurements must be evaluated in conjunction with information on the species composition. Species composition data must be collected at the same time as ground cover observations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

<u>2. Woody-Plant Stocking</u> The success of forestry is determined by comparing the reclaimed forest area to a technical standard.

Use of Reference Areas. Reference areas are not applicable for woody plant stocking in the forestry land use.

Use of Technical Standards. The stocking rate success standards for woody plant species will be permit-specific and site-specific. Success standards for stocking rates will be developed by the applicant through consultation with the Texas Forest Service (The Texas A&M University System), in accordance with guidelines included in Attachment 3. Success standards will be subject to review and comment during the permit review and will be approved by the Texas Forest Service.

<u>Statistical Comparison</u>: Compare the mean stem count of the reclaimed area to 90% of the appropriate stem count standard (also called the lowest acceptable value). The lowest acceptable value is obtained by multiplying the technical standard (for the appropriate tree type and region) by 0.9 (i.e. 350 stems/acre X 0.9 = 315 stems/acre). If the reclaimed area stem count is equal to or greater than the lowest acceptable value, there is no need to calculate a confidence interval (in this case, the reclaimed area will have met revegetation success). If the reclaimed area stem count is less than the lowest acceptable value, perform a hypothesis test,

using a one-sided 90% confidence interval (see Appendix A, normally-distributed data). An example of the calculations is found in Appendix C.

Species Composition. Woody-plant stocking measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as woody-plant count evaluations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

D. Fish and Wildlife Habitat

Two vegetation parameters are measured for fish and wildlife habitat: ground cover and woody-plant stocking rates. Fish and wildlife habitat is land that is dedicated wholly or partially to the production, protection, or management of species of fish or wildlife.

1. Ground Cover. The ground cover values of mined, revegetated areas are compared to an approved technical standard. The ground cover of the reclaimed fish and wildlife habitat must be within 90% of the success standard with a 90% statistical confidence.

Use of Reference Areas. Reference areas are not applicable for ground cover in the fish and wildlife habitat land use.

Use of General Technical Standard. The technical standard is 78% ground cover.

Use of Bobwhite Quail and Other Grassland Bird Species Technical Standard. The technical standard is 63% - 70% ground cover.

Erosion of landscapes is a natural process dependent on relief, type of geologic material, precipitation, and vegetative cover. Appropriate reclamation land use planning takes these factors into account and will ensure in all cases ground cover will be adequate to control erosion.

Statistical Comparison: Compare the reclaimed area ground cover estimate to 90% of the technical ground cover standard (also called the lowest acceptable value). Obtain the lowest acceptable value by multiplying the appropriate technical standard (re: precipitation level) by 0.9 [i.e. General: 78% X 0.9 = 70%]. The success standard for Bobwhite Quail habitat ground cover reflects a range since the technical standard is expressed as a range with a lower and upper value. For this habitat the success standard range is reflected by the lowest value of 57% [63% X 0.9] and the highest value of 77% [70% X 0.1]. If the reclaimed area ground cover is equal to or greater than the lowest acceptable value, or in the case of Bobwhite Quail habitat also equal to or less than the highest acceptable value, there is no need to calculate a confidence interval (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area ground cover does not meet the acceptable value(s), perform a hypothesis test, using a one-sided 90% confidence interval (see Appendix A, binomially-distributed data). Examples of calculations are found in Appendix C.

Species Composition. Ground cover measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as ground cover observations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

<u>2. Woody-Plant Stocking</u> The success of fish and wildlife habitat is measured by comparing the reclaimed habitat to a technical standard.

Use of Reference Areas. Reference areas are not applicable for woody-plant stocking in the fish and wildlife habitat land use.

Use of Technical Standards. The stocking rates for woody plant species will be permit-specific and site-specific. Stocking rates will be developed by the applicant through consultation with the Texas Parks and Wildlife Department, in accordance with guidelines included in Attachment 2. Success standards will be subject to review and comment during the permit review and will be approved by the Texas Parks and Wildlife Department.

Motte locations planted to support Bobwhite Quail and other grassland bird species habitat shall be mapped at the time of planting. The success of woody plant stocking (stem count) will be based on meeting or exceeding the technical standard for motte density per acre and by counting the number of stems per motte.

<u>Statistical Comparison</u>: Compare the mean stem count of the reclaimed area to 90% of the appropriate stem count standard (also called the lowest acceptable value). First, choose the appropriate technical standard (based on the appropriate use [motte, corridor, etc.] and region). Second, multiply the technical standard by 0.9 to obtain the lowest acceptable value. If the reclaimed area stem count is equal to or greater than the lowest acceptable value, there is no need to calculate a one-sided 90% confidence interval (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, a confidence interval must be calculated (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

Species Composition. Woody-plant stocking measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as woody-plant count evaluations. Seventy-five percent (75%) of the ground cover must be comprised of species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

E. Undeveloped Land

Undeveloped land (no current use or land management) is land that is undeveloped or, if previously developed, land that has been allowed to return naturally to an undeveloped state or has been allowed to return to forest through natural succession. Two vegetation parameters are measured for undeveloped land: ground cover and woody-plant stocking rates.

1. Ground Cover. The ground cover values of mined, revegetated areas are compared to approved technical standards.

Use of Reference Areas. Reference areas are not applicable for ground cover in undeveloped land use.

Use of Technical Standards. The following steps should be followed when measuring for revegetation success.

Moisture Regime and Vegetation Growth Form: The choice of technical standards to employ depends on the dominant vegetation growth form found in the undeveloped land. There are two situations: grasses are the dominant growth forms or woody species are dominant. For instances where grasses are predominant, the technical standards will be affected by amount of average annual precipitation and the grass type. For areas with an average annual precipitation greater than 26 inches, the following technical standards will be used: 1) Sod-forming grasses: ground cover standard is 95%; 2) Bunch grass mixtures: ground cover standard is 90%. For areas with an average annual precipitation less than or equal to 26 inches, the following technical standards will be used: 1) Sod-forming grasses: ground cover standard is 90%; 2) Bunch grass mixtures: ground cover standard is 80%. For instances where woody species are predominant, the technical standard is 78% ground cover.

Statistical Comparison: Compare the ground cover estimate to 90% of the appropriate ground cover standard (also called the lowest acceptable value). Obtain the lowest acceptable value by multiplying the appropriate technical standard (re: vegetation growth form and, if appropriate, moisture regime) by 0.9 (i.e.: 95% X 0.9 = 85.5%). If the reclaimed area ground cover is equal to or greater than the lowest acceptable value, there is no need to calculate a confidence interval (in this case, the reclaimed area will have met the revegetation success standard). If the reclaimed area ground cover is less than the lowest acceptable value, calculate a one-sided 90% confidence interval (see Appendix A, binomially-distributed data). Example of calculations are found in Appendix C.

Species Composition. Ground cover measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as ground cover observations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

2. Woody-Plant Stocking The revegetation success of undeveloped land is measured by comparing the reclaimed area to a technical standard.

Use of Reference Areas. Reference areas are not applicable for woody-plant stocking in undeveloped land use.

Use of Technical Standards. The stocking rates for woody plant species will be permit-specific and site-specific. Stocking rates will be developed by the applicant through consultation with the Texas Parks and Wildlife Department, in accordance with guidelines included in Attachment 2. Success standards will be subject to review and comment during the permit review and will be approved by the Texas Parks and Wildlife Department.

Statistical Comparison: Compare the mean stem count of the reclaimed area to 90% of the appropriate stem count standard (also called the lowest acceptable value). First, choose the appropriate technical standard (based on the appropriate use [motte, corridor, etc.] and region). Second, multiply the technical standard by 0.9 to obtain the lowest acceptable value. If the reclaimed area stem count is equal to or greater than the lowest acceptable value, there is no need to calculate a one-sided 90% confidence interval (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, a confidence interval must be calculated (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

Species Composition. Woody-plant stem count measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as woody-plant stem count evaluations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

F. Industrial / Commercial

Industrial/Commercial land uses can involve either; 1.) extraction or transformation of materials for fabrication of products, wholesaling of products, or for long-term storage of products or, 2.) retail or trade of goods or services. Two vegetation parameters may be measured for industrial/commercial land: ground cover sufficient to control erosion and woody-plant stocking rates (where woody-plant stocking is implemented).

1. Ground Cover. Adequate ground cover to control erosion is required (based on Revised Universal Soil Loss Equation).

2. Woody-Plant Stocking. The revegetation success of industrial/commercial land is measured by comparing the reclaimed area to a technical standard.

Use of Reference Areas. Reference areas are not applicable for woody-plant stocking in industrial/commercial land use.

Use of Technical Standards. The stocking rates for woody plant species will be permit-specific and site-specific. Stocking rates will be developed by the applicant through consultation with the Texas Parks and Wildlife Department, in accordance with guidelines included in Attachment 2. Success standards will be subject to review and comment during the permit review and will be approved by the Texas Parks and Wildlife Department.

Statistical Comparison: Compare the mean stem count of the reclaimed area to 90% of the appropriate stem count standard (also called the lowest acceptable value). First, choose the appropriate technical standard (based on the appropriate use [motte, corridor, etc.] and region). Second, multiply the technical standard by 0.9 to obtain the lowest acceptable value. If the reclaimed area stem count is equal to or greater than the lowest acceptable value, there is no need to calculate a one-sided 90% confidence interval (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, a confidence interval must be calculated (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

Species Composition. Woody-plant stem count measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as woody-plant stem count evaluations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

G. Residential

Residential land use includes single- and multiple-family housing, mobile home parks, and other residential lodgings. Two vegetation parameters may be measured for residential land: ground cover sufficient to control erosion and woody-plant stocking rates (where woody-plant stocking is implemented).

1. Ground Cover. Adequate ground cover to control erosion is required (based on Revised Universal Soil Loss Equation).

2. Woody-Plant Stocking. The revegetation success of residential land is measured by comparing the reclaimed area to a technical standard.

Use of Reference Areas. Reference areas are not applicable for woody-plant stocking in residential land use.

Use of Technical Standards. The stocking rates for woody plant species will be permit-specific and site-specific. Stocking rates will be developed by the applicant through consultation with the Texas Parks and Wildlife Department, in accordance with guidelines included in Attachment 2. Success standards will be subject to review and comment during the permit review and will be approved by the Texas Parks and Wildlife Department.

Statistical Comparison: Compare the mean stem count of the reclaimed area to 90% of the appropriate stem count standard (also called the lowest acceptable value). First, choose the appropriate technical standard (based on the appropriate use [motte, corridor, etc.] and region). Second, multiply the technical standard by 0.9 to obtain the lowest acceptable value. If the reclaimed area stem count is equal to or greater than the lowest acceptable value, there is no need to calculate a one-sided 90% confidence interval (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, a confidence interval must be calculated (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

Species Composition. Woody-plant stem count measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as woody-plant stem count evaluations. Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

H. Recreation

Recreation land use involves public or private leisure-time use, including developed recreation facilities such as parks, camps, and amusement areas, as well as areas for less intensive uses such as hiking, canoeing, and other undeveloped recreational uses. Two vegetation parameters are measured for recreational land: ground cover sufficient to control erosion and woody-plant stocking rates.

1. Ground Cover. Adequate ground cover to control erosion is required (based on Revised Universal Soil Loss Equation).

2. Woody-Plant Stocking. The revegetation success of recreation land use is measured by comparing the reclaimed area to a technical standard.

Use of Reference Areas. Reference areas are not applicable for woody-plant stocking in recreation land use.

Use of Technical Standards. The stocking rates for woody plant species will be permit-specific and site-specific. Stocking rates will be developed by the applicant through consultation with the Texas Parks and Wildlife Department, in accordance with guidelines included in Attachment 2. Success standards will be subject to review and comment during the permit review and will be approved by the Texas Parks and Wildlife Department.

Statistical Comparison: Compare the mean stem count of the reclaimed area to 90% of the appropriate stem count standard (also called the lowest acceptable value). First, choose the appropriate technical standard (based on the appropriate use [motte, corridor, etc.] and region). Second, multiply the technical standard by 0.9 to obtain the lowest acceptable value. If the reclaimed area stem count is equal to or greater than the lowest acceptable value, there is no need to calculate a one-sided 90% confidence interval (in this case, the reclaimed area would have met the revegetation success standard). If the reclaimed area productivity is less than the lowest acceptable value, a confidence interval must be calculated (see Appendix A, normally-distributed data). An example of the calculations can be found in Appendix C.

Species Composition. Woody-plant stem count measurements must be evaluated in conjunction with information on the species composition of the stands. Species composition data are collected at the same time as woody-plant stem count evaluations. . Seventy-five percent (75%) of the ground cover must be comprised of permit-approved species which support the land use, from the planting list in the reclamation plan. The remaining twenty-five percent (25%) can be comprised of desirable invader species as established and approved in the permit by land use.

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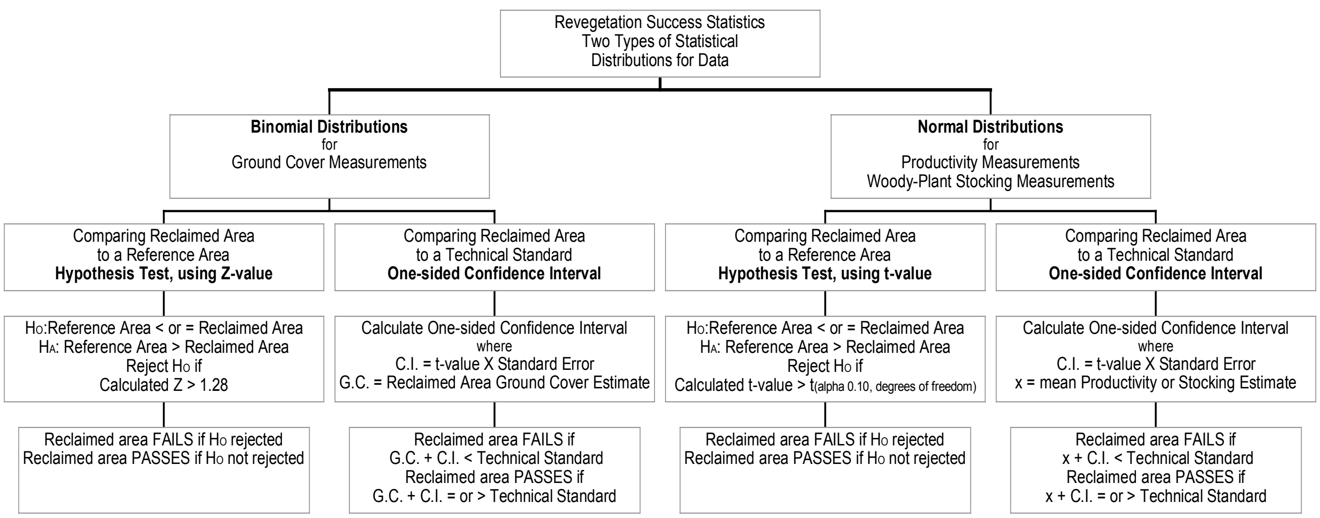
Appendix A. Statistical Information (Equations and Table)

Appendix A
Statistical Information (Equations and Table)

There are several different statistical operations involved in the determination of revegetation success, since there are two types of statistical distributions for revegetation data: binomial and normal (see chart below for a summary). Ground cover measurements are distributed binomially, since there are only two outcomes (either a hit or a miss). Productivity and woody-plant stocking measurements are distributed normally. The statistics for both of the latter parameters must involve normal distributions.

Summary of Revegetation Success Statistics



Binomially-Distributed Revegetation Data

<u>Sample Number</u>

Enough samples (measurements) must be taken to properly characterize the mean ground cover. A statistically adequate sample size is needed to ensure that there are enough samples to characterize the mean value of ground cover, within a certain level of precision (which the Commission has established at 10% of the mean). Attainment of a statistically adequate sample size is a function of the actual ground cover and the number of samples taken (in general, fewer samples are needed with increasing ground cover percentages).

There is no simple “test” for determining a statistically adequate sample size for ground cover measurements, as there is for normally-distributed data. The way to assess that there is a statistically adequate sample consists of verifying that the maximum error relative to the mean is equal or less than 10%. The maximum error relative to the mean for ground cover measurements is obtained with the following equations:

$$\text{Maximum Error Relative to the Mean, \%} = \frac{\text{t - value X Standard Error}}{\text{Ground Cover Estimate}} \text{ X } 100 \,,$$

where

- t-value: select the t-value for a two-sided test with 90% confidence (where $^{\alpha}/_{2}$). See Table A-1 in Appendix A. The degrees of freedom are equal to n -1. The t-value X Standard Error is equivalent to the confidence interval.

$$\text{Standard Error: } SE(\hat{p}) = \sqrt{\frac{\hat{p}\,(100 - \hat{p})}{n}} \,, \text{ where}$$

- $\hat{p}$ is the ground cover estimate
- n is the number of samples taken to obtain the ground cover estimate.

NOTE: t-values for two-sided tests are only used for calculations to determine sample number. A statistically adequate sample size has been obtained when the maximum error relative to the mean is equal to or less than 10%.

Standard Error

The standard error for binomial distributions (i.e. ground cover) is calculated using the following equation:

$$SE(\hat{p}) = \sqrt{\frac{\hat{p}\,(100 - \hat{p})}{n}} \,, \text{ where}$$

- $\hat{p}$ = the percent ground cover, for example 85%.
- n = the number of observations

Confidence Interval

Confidence intervals are used when the ground cover of a reclaimed area is compared to a technical standard as a measure of revegetation success. The confidence interval for a ground cover estimate is required when the estimate is less than the lowest acceptable value (90% of the technical standard). There is a regulatory requirement that a one-sided test be used where the alpha error is 0.10 (this provides a 90% confidence interval).

$$\text{One - sided Confidence Interval} = \hat{p} + [t_{\alpha,df} \text{ X } SE(\hat{p})] \,, \text{ where}$$

- $\hat{p}$ = percent ground cover
- $t_{\alpha,df}$ = t-value for one-sided test, see table A-1 (degrees of freedom to use are equal to n - 1). Alpha error (α) equals 0.10.
- $SE(\hat{p})$ = the standard error of the estimated ground cover (see above).

The ground cover of the reclaimed area meets the technical performance standard if the one-sided 90% confidence interval equals or exceeds the lowest acceptable value (i.e. a ground cover of

85%, plus a confidence interval of 3% [totaling 88%], would exceed a lowest acceptable value of 87%). The ground cover of the reclaimed area would not meet the technical performance standard if the ground cover estimate plus the confidence interval add up to a value less than the lowest acceptable value.

Hypothesis Test using Z-value (Z-test)

A Z-test is used when the ground cover of a reclaimed area is compared to that of a reference area as a measure of revegetation success. This test statistic is used for hypothesis tests.

The hypothesis test for comparison of two ground cover proportions is based on the normal approximation to the binomial distribution (the simplied version of the equation follows immediately):

$$Z = \left(\hat{p}_1 - \hat{p}_2\right) / [\hat{p}(1-\hat{p})(n_1 + n_2)/n_1 n_2]^{1/2}$$

The equation was obtained from Ostle & Mensing (1982); where $\hat{p}_1$ is equal to the reference area ground cover proportion and $\hat{p}_2$ is equal to the reclaimed area ground cover proportion. The test statistic (Z) is equal to the difference between the two binomial proportions divided by the pooled standard error of the two binomial proportions:

$$\text{Calculated } Z = \frac{0.9\hat{p}_1 - \hat{p}_2}{SE\ (\hat{p}_1 - \hat{p}_2)}$$

Let $0.9\hat{p}_1$ equal the lowest acceptable value (90% of the reference area percent ground cover) and $\hat{p}_2$ equal the reclaimed area proportion. The pooled standard error (SE) is calculated with the following equation (where the full value of the reference area ground cover is used):

$$SE\ (\hat{p}_1 - \hat{p}_2) = \sqrt{\frac{\hat{p}_1(100 - \hat{p}_1)}{n_1} + \frac{p_2(100 - \hat{p}_2)}{n_2}}$$

Hypothesis Tests:

H_O: Reference Area Ground Cover ≤ Reclaimed Area Ground Cover
H_A: Reference Area Ground Cover > Reclaimed Area Ground Cover

Reject H_O if Calculated Z > 1.28
(A Z-value of 1.28 corresponds to the critical level for a one-sided alpha error of 0.10)

Summary: The null hypothesis (identified as H_O) states that the reference area ground cover value is equal to or less than that from the reclaimed area. The alternative hypothesis states that the reference area ground cover value is greater than that from the reclaimed area. The null hypothesis is not rejected if the calculated Z is equal to or less than 1.28. Conversely, the null hypothesis rejected if calculated Z is greater than 1.28. The reclaimed area does not meet the performance standard when the null hypothesis is rejected. The reclaimed area meets the performance standard when the null hypothesis is not rejected.

Normally-Distributed Revegetation Data

Sample Number

Enough samples (measurements) must be taken to properly characterize the mean productivity or woody-plant stocking rate. A statistically adequate sample size is needed to ensure that there are enough samples to characterize the mean value of productivity or stocking, within a certain level of precision (which the Commission has established at 10% of the mean). Attainment of a statistically adequate sample size is a function of the variability of data and the number of samples taken (in general, fewer samples are needed with less variable data).

The following equation is used to estimate the number of samples required to adequately measure the mean value of a normally-distributed population (if samples have already been taken and a preliminary estimate of the variance and mean are available). The estimated sample number is affected by the population's variability.

$$N = \frac{\left(s^2 \times t^2\right)}{\left(d \times \bar{x}\right)^2}, \text{ where:}$$

- N = Total number of sample required
- s^2 = Variance = $\frac{\sum (x - \bar{x})^2}{(n-1)^2}$ (Note: standard deviation is equal to $\sqrt{\text{variance}}$).
- x = Individual measurements of undried weights or stem counts
- $\bar{x}$ = The mean (average) of undried weights or stem counts
- n = The actual number of samples collected
- t = t-value for 90% confidence t = t-value for 90% confidence, see table A-1 (degrees of freedom to use are equal to n - 1).
- d = the desired precision (maximum error relative to the mean); d = 0.1 for 10%.

It is possible for a recalculated N value (resulting from additional sampling) to be less than the sample size after initial sampling, since additional measurements may establish a lower variance for the evaluation area. However, all samples taken must be used for later statistical calculations.

Standard Error

The standard error for estimates of the mean (i.e. productivity and mean woody plant stem counts) is calculated using the following equation:

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}, \text{ where}$$

- s = the standard deviation
- n = the number of observations

Confidence Interval

Confidence intervals are used when the mean productivity or stocking rate of a reclaimed area is compared to a technical standard as a measure of revegetation success. The confidence interval for either the mean productivity or the woody-plant stocking rate is required when the estimate is less than the lowest acceptable value (90% of the technical standard). There is a regulatory requirement that a one-sided test be used where the alpha error is 0.10 (this provides a 90% confidence interval).

$$\text{One - sided Confidence Interval} = \bar{x} + [t_{\alpha,df} \text{ X } SE(\hat{p})], \quad \text{where}$$

- $\bar{x}$ = estimated mean (either productivity or woody-plant stem count)
- $t_{\alpha,df}$ = t-value for one-sided test, see table A-1 (degrees of freedom to use are equal to n - 1). Alpha error (α) equals 0.10.
- $SE(\hat{p})$ = the standard error of the mean (see above)

The mean productivity or stocking of the reclaimed area meets the technical performance standard if the one-sided 90% confidence interval equals or exceeds the lowest acceptable value (i.e. a mean reclaimed area productivity of 2.4 tons, plus a confidence interval of 0.2 tons/acre [totaling 2.6 tons/acre], would exceed a lowest acceptable value of 2.5 tons/acre). The mean productivity or stocking of the reclaimed area would not meet the technical performance standard if the ground cover estimate plus the confidence interval add up to a value less than the lowest acceptable value.

Hypothesis Test using t-value (t-test)

A t-test is used when the mean productivity or stocking rate of a reclaimed area is compared to that of a reference area as a measure of revegetation success. This test statistic is used for hypothesis tests.

The t statistic compares the difference of the means to the pooled standard error of the two areas.

$$\text{Calculated t - value} = \frac{[0.9\bar{x}_1 - \bar{x}_2]}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

- $0.9\bar{x}_1$ = lowest acceptable value (90% of estimated mean [productivity or stocking]) from the reference area
- $\bar{x}_2$ = estimated mean (productivity or stocking) from the reclaimed area
- s_1 = variance of the data from the reference area
- s_2 = variance of the data from the reclaimed area
- n_1 = number of observations taken in the reference area
- n_2 = number of observations taken in the reclaimed area

Hypothesis Tests:

H_O: Reference Area Mean ≤ Reclaimed Area Mean

H_A: Reference Area Mean Cover > Reclaimed Area Mean

Reject H_O if Calculated $t > t_{\alpha, (d.f.)}$, where

$t_{\alpha, (d.f.)}$ is the one-sided test t-value obtained from Table A-1. The α (alpha error) is equal to 0.10. The degrees of freedom (d.f.) will depend on the variance of the two areas:

<u>Where both areas (reclaimed and reference) have equal variances</u>, the degrees of freedom are obtained with the following equation:

$$\text{degrees of freedom (d.f.)} = n_1 + n_2 - 2$$

<u>Where areas have unequal variances</u>, the degrees of freedom are obtained with the following equation (from Helsel and Hirsch, 1992):

$$\text{degrees of freedom (d.f.)} = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\left(\frac{s_1^2/n_1}{n_1 - 1}\right)^2 + \left(\frac{s_2^2/n_2}{n_2 - 1}\right)^2}$$

Summary: The null hypothesis (identified as H_O) states that the reference area mean productivity or stocking is equal to or less than that from the reclaimed area. The alternative hypothesis states that the reference area mean productivity or stocking is greater than that from the reclaimed area. The null hypothesis is not rejected if the calculated t-value is equal to or less than the appropriate t-value from Table A-1. Conversely, the null hypothesis rejected if the calculated t-value is greater than the appropriate t-value from Table A-1. The reclaimed area does not meet the performance standard when the null hypothesis is rejected. The reclaimed area meets the performance standard when the null hypothesis is not rejected.

Table A-1. Cumulative *t* distribution.

Degrees of Freedom (n-1)	*p* 0.90 One-sided Tests (α = 0.10)	*p* 0.95 Two-sided Tests ($^{\alpha}/_{2}$ = 0.05) †
1	3.078	6.314
2	1.886	2.920
3	1.638	2.353
4	1.533	2.132
5	1.476	2.015
6	1.440	1.943
7	1.415	1.895
8	1.397	1.860
9	1.383	1.833
10	1.372	1.812
11	1.363	1.796
12	1.356	1.782
13	1.350	1.771
14	1.345	1.761
15	1.341	1.753
16	1.337	1.746
17	1.333	1.740
18	1.330	1.734
19	1.328	1.729
20	1.325	1.725
21	1.323	1.721
22	1.321	1.717
23	1.319	1.714
24	1.318	1.711
25	1.316	1.708
26	1.315	1.706
27	1.314	1.703
28	1.313	1.701
29	1.311	1.699
30	1.310	1.697
35	1.306	1.690
40	1.303	1.684
45	1.301	1.680
50	1.299	1.676
55	1.297	1.673
60	1.296	1.671
70	1.294	1.667
80	1.293	1.665
90	1.291	1.662
100	1.290	1.661
200	1.286	1.653
300	1.285	1.650
400	1.284	1.649
500	1.284	1.648
1000	1.283	1.647
∞	1.28155	1.64485

Source: Adapted from Appendix 5 of Ostle and Mensing, 1975, *Statistics in Research*, 3rd ed., The Iowa State University Press. Entries in the table are values of t_p where $p = P(t \leq t_p)$.

† Value used for statistically adequate sample tests.

Table 8. Cumulative *t* distribution.

Appendix B. Summary of Revegetation Success Standards

(Revised June 14, 2006)

Appendix B
Summary of Revegetation Success Standards

<table>
<tr><th>Land Use</th><th>Revegetation Parameter and Performance Standards</th><th>Conditions for Bond Release</th></tr>
<tr><td rowspan="2">Grazingland and Pastureland</td><td>Ground Cover
90% of the Reference Area
or
90% of the Following Technical Standards:
<u>For Areas with Annual Precipitation > 26 inches</u>
Bunch-type Grasses 90% — Rhizomatous Grasses 95%
<u>For Areas with Annual Precipitation ≤ 26 inches</u>
Bunch-type Grasses 80% — Rhizomatous Grasses 90%
(Species Composition also measured)</td><td rowspan="2">For Areas with Annual Precipitation >26”
(5-year ERP)
Performance Standards must be met for any 2 years, except the first year

For Areas with Annual Precipitation ≤26”
(10-year ERP)
Performance standards must be met in at least the last 2 consecutive years</td></tr>
<tr><td>Productivity
90% of the Reference Area
or
90 % of the Following Technical Standards:
Site-specific technical standards developed by the USDA-NRCS at the request of the permittee.</td></tr>
<tr><td rowspan="2">Cropland -- Non-Prime</td><td>Ground Cover
Maintain enough ground cover to control erosion until crop production begins (Rev. Univ. Soil Loss Eq’n.)</td><td rowspan="2">Annual Precipitation >26”
(5-year ERP) Performance standards must be met for any 2 yrs. except the 1st yr.
Annual Precipitation ≤ 26”
(10-year ERP)
Performance standards must be met in at least the last 2 consecutive years</td></tr>
<tr><td>Productivity
90% of the Reference Area
or
90% of the Following Technical Standards:
Site-specific technical standards developed by the USDA-NRCS at the request of the permittee</td></tr>
<tr><td rowspan="2">Cropland -- Restored Prime Farmland Soils</td><td>Ground Cover
Maintain enough ground cover to control erosion until crop production begins (Rev. Univ. Soil Loss Eq’n.)</td><td rowspan="2">Measurement of soil productivity shall be initiated within 10 years after completion of soil eplacement; shall be a minimum of 3 crop years prior to bond release.

For Areas with Annual Precipitation > 26”
(5-year ERP)
Performance Standards can be measured in any of ERP years except the first.

For Areas with Annual Precipitation ≤ 26”
(10-year ERP)
Performance Standards must be met in at least the last 2 consecutive years of the ERP.</td></tr>
<tr><td>Productivity
Reference areas not applicable

100% of the Following Technical Standard:
Reference crops shall be selected from the crops most commonly produced on the surrounding prime farmland. Only 2 of the 3 required crop years may involve forage crops. Where row crops are the dominant crop grown on prime farmland in the area, the row crop requiring the greatest rooting depth shall be chosen as one of the reference crops. Selection of reference crops must be accomplished through consultation with the USDA-NRCS, with documentation of such included in the permit application. Reference crop yields will be compared to average yields for specific prime farmland series. Average yields will be obtained through consultation with the USDA-NRCS.</td></tr>
</table>

Land Use	Revegetation Parameter and Performance Standards	Conditions for Bond Release
Forestry	**Ground Cover** 90% of the Reference Area or 90% of the Following Technical Standard: 78% *(Species Composition also measured)*	• Areas shall equal or exceed the ground cover success standard during the growing season of the last year of the responsibility period
	Woody-Plant Stocking Rate Reference areas not applicable 90% of the Following Technical Standard: Site-specific success standards will be developed by the permittee through consultation with the Texas Forest Service (Texas A&M Univ.). Standards will be approved by the Texas Forest Service. *(Species Composition also measured)*	• Woody plants that will be used for revegetation success shall be healthy & have been in place for not less than 2 growing seasons. At the time of bond release, at least 80% of the trees and shrubs shall have been in place for 60% of the ERP
Fish and Wildlife Habitat	**Ground Cover** Reference areas not applicable 90% of the Following General Technical Standard: 78% 90% (lower limit) and 110% (upper limit) of the following Bobwhite Quail and Grassland Bird Species technical standard 63% - 70% *(Species Composition also measured)*	• Areas shall equal or exceed the ground cover success standard during the growing season of the last year of the responsibility period
	Woody-Plant Stocking Rate Reference areas not applicable 90% of the Following Technical Standard except for mottes used to support Bobwhite Quail and Grassland Bird Species, the standard for which is based on meeting or exceeding the following Technical Standard: Site-specific success standards will be developed by the permittee through consultation with the Texas Parks and Wildlife Department. Standards will be approved by the Texas Parks and Wildlife Dept. *(Species Composition also measured)*	• Woody plants that will be used for revegetation success shall be healthy & have been in place for not less than 2 growing seasons. At the time of bond release, at least 80% of the healthy trees and shrubs shall have been in place for 60% of the ERP
Undeveloped Land	**Ground Cover** Reference areas not applicable 90% of the Following Technical Standards: Predominantly Grass Species: *For Areas with Annual Precipitation > 26 inches* Rhizomatous: 95% Bunch-type: 90% *For Areas with Annual Precipitation $\leq$ 26 inches* Rhizomatous: 90% Bunch-type: 80% Predominantly Woody Species : 78% *(Species Composition also measured)*	• Areas shall equal or exceed the ground cover success standard during the growing season of the last year of the responsibility period
	Woody-Plant Stocking Rate Reference areas not applicable 90% of the Following Technical Standard: Site-specific success standards will be developed by the permittee through consultation with the Texas Parks and Wildlife Department. Standards will be approved by the Texas Parks and Wildlife Dept.	• Woody plants that will be used for revegetation success shall be healthy & have been in place for not less than 2 growing seasons. At the time of bond release, at least 80% of the healthy trees and shrubs shall have been in place for 60% of the

	(Species Composition also measured)	been in place for 60% of the ERP

Land Use	Revegetation Parameter and Performance Standards	Conditions for Bond Release
Industrial/Commercial	**Ground Cover** Maintain enough ground cover to control erosion (Revised Universal Soil Loss Equation)	Woody plants that will be used for revegetation success shall be healthy & have been in place for not less than 2 growing seasons. At the time of bond release, at least 80% of the trees and shrubs shall have been in place for 60% of the ERP
	Woody-Plant Stocking Rate (Only Where Woody-Plant Stocking is Implemented) Reference areas not applicable 90% of the Following Technical Standard: Site-specific success standards will be developed by the permittee through consultation with the Texas Forest Service (Texas A&M Univ.). Standards will be approved by the Texas Forest Service *(Species Composition also measured)*	
Residential	**Ground Cover** Maintain enough ground cover to control erosion (Revised Universal Soil Loss Equation)	Woody plants that will be used for revegetation success shall be healthy & have been in place for not less than 2 growing seasons. At the time of bond release, at least 80% of the healthy trees and shrubs shall have been in place for 60% of the ERP
	Woody-Plant Stocking Rate (Only Where Woody-Plant Stocking is Implemented) Reference areas not applicable 90% of the Following Technical Standard: Site-specific success standards will be developed by the permittee through consultation with the Texas Parks and Wildlife Department. Standards will be approved by the Texas Parks and Wildlife Dept. *(Species Composition also measured)*	
Recreation	**Ground Cover** Maintain enough ground cover to control erosion (Revised Universal Soil Loss Equation)	Woody plants that will be used for revegetation success shall be healthy & have been in place for not less than 2 growing seasons. At the time of bond release, at least 80% of the healthy trees and shrubs shall have been in place for 60% of the ERP
	Woody-Plant Stocking Rate Reference areas not applicable 90% of the Following Technical Standard: Site-specific success standards will be developed by the permittee through consultation with the Texas Parks and Wildlife Department. Standards will be approved by the Texas Parks and Wildlife Dept. *(Species Composition also measured)*	

Appendix C. Examples of Revegetation Success Determinations

Appendix C
Examples of Revegetation Success Determinations

Ground Cover

Example 1. Ground cover for a postmining land use of pastureland, in a region with 34 inches of average annual rainfall. The revegetation success criteria will be based on technical standards, since a reference area was not used. The ground cover standards are 95% for sod-forming/rhizomatous grasses and 90% for bunchgrasses for that moisture regime.

The survey method used was baseline sampling with multiple random starts. The cover measurements were obtained with a point frequency method, using a crosswire sighting device. Ninety-seven observations were taken (the goal for ground cover measurements is 100 observation points; however, the actual sample number will be affected by transect dimensions and field conditions).

Survey Results (from 97 observation points):
Observation points where vegetation was intercepted ("hits"): 92 of 97
Breakdown of vegetation hits

- Permit-approved species: 86 of 92
  - Coastal bermudagrass 65 of 86
  - Common bermudagrass 11 of 86
  - Kleingrass 10 of 86
- Litter: 2 of 92
- Non permit-approved species: 4 of 92

Observation points where bare ground intercepted ("misses"): 5 of 97

Ground Cover Calculations
The estimated ground cover was 90.7% (88 of 97).

- Vegetation hits were 88 of 97, instead of 92 of 97, because we excluded 4 vegetation "hits" that were comprised of non permit-approved undesirable species.
- 75.6% of the ground cover from permit-approved species was coastal bermudagrass (65 of 86)
- 12.8% of the ground cover from permit-approved species was common bermudagrass (11 of 86)
- 11.6% of the ground cover from permit-approved species was kleingrass (10 of 86)

Statistically Adequate Sample Size
1st calculate the standard error:

$$\text{Standard error} = \sqrt{\frac{90.7\,(100\ -\ 90.7\,)}{97}}\ =\ 2.95;\ \text{then}$$

calculate the maximum error relative to the mean:

- t-value = 1.661
- ground cover estimate = 90.7%

Max. Error Relative to the Mean $= \frac{1.661 \times 2.95}{90.7} \times 100 = 5.4\%$; therefore, a statistically adequate sample size was obtained (since it was less than or equal to 10%).

Statistical Comparison to Technical Standard
The ground cover standards must be adjusted since there were several types of grasses present (both sod-forming/rhizomatous and bunch-type).

- Sod-forming/rhizomatous species: 88.4%
- Bunchgrass species: 11.6%
- Technical Standard is therefore 94.4%, obtained by combining the following:
  - 0.884 X 95% cover (technical standard for sod-forming/rhizomatous grasses)
  - 0.116 X 90% cover (technical standard for bunchgrasses)

The estimated ground cover was 90.7%, while the lowest acceptable value was 85.0% (90 percent of the 94.4% technical standard); therefore, calculation of a confidence interval is not necessary. Conclusion: for the ground cover parameter, the amount of cover estimated indicates that there **is** revegetation success.

Example 2. Ground cover for a postmining land use of grazingland, in a region with 27 inches of average annual rainfall. The revegetation success criteria will be based on technical standards, since a reference area was not used. The ground cover standards are 95% for sod-forming/rhizomatous grasses and 90% for bunchgrasses for that moisture regime.

The survey method used was baseline sampling with multiple random starts. The cover measurements were obtained with a point frequency method, using a crosswire sighting device. One hundred observations were taken.

Survey Results (from 100 observation points):
Observation points where vegetation was intercepted ("hits"): 88 of 100
Breakdown of vegetation hits

- Permit-approved species: 78 of 88
  - Alamo switchgrass 57 of 78
  - Indiangrass 6 of 78
  - Sideoats grama 3 of 78
  - Buffalograss 9 of 78
  - Common bermudagrass 3 of 78
- Litter: 1 of 88
- Non permit-approved species: 9 of 88

Observation points where bare ground intercepted ("misses"): 12 of 100

Ground Cover Calculations
The estimated ground cover was 79% (79 of 100).

- Vegetation hits were 79 of 100, instead of 88 of 100, because we excluded 9 vegetation "hits" that were comprised of non permit-approved undesirable species.
- 73.1% of the ground cover from permit-approved species was Alamo switchgrass (57 of 78)
- 7.7% of the ground cover from permit-approved species was indiangrass (6 of 78)
- 3.8% of the ground cover from permit-approved species was sideoats grama (3 of 78)
- 11.5% of the ground cover from permit-approved species was buffalograss (7 of 78)

- 3.8% of the ground cover from permit-approved species was common bermudagrass (3 of 78)

Statistically Adequate Sample Size

1st calculate the standard error:

$$\text{Standard error} = \sqrt{\frac{79\ (100\ -\ 79\ )}{100}}\ =\ 4.07;\ \text{then}$$

calculate the maximum error relative to the mean:

- t-value = 1.661
- ground cover estimate = 79%

Max. Error Relative to the Mean $= \frac{1.661 \times 4.07}{79} \times 100 = 8.6\%$; therefore, a statistically adequate sample size was obtained (since it was less than or equal to 10%).

Statistical Comparison to Technical Standard

The ground cover standards must be adjusted since there were several types of grasses present (both bunch-type and sod-forming/rhizomatous).

- Bunchgrass species: 84.6%
- Sod-forming/rhizomatous species: 15.3%
- Technical Standard is therefore 90.7%, obtained by combining the following:
  - ∗ 0.846 X 90% cover (technical standard for bunchgrasses)
  - ∗ 0.153 X 95% cover (technical standard for sod-forming/rhizomatous grasses)

The estimated ground cover was 79%, while the lowest acceptable value was 81.6% (90 percent of the 90.7% technical standard); therefore, the calculation of a confidence interval **is necessary**. A one-sided 90% statistical confidence (α = 0.10) interval for the ground cover estimate must be calculated in order to determine whether revegetation success has been achieved.

- First, the standard error of the ground cover is calculated using the following equation:
-

$$SE(\hat{p})\ =\ \sqrt{\frac{\hat{p}\ (100\ -\ \hat{p})}{n}},\ \ \text{where}$$

  - ∗ $\hat{p}$ is the percent ground cover
  - ∗ n is the number of observations

$$SE(\hat{p})\ =\ \sqrt{\frac{79\ (100\ -\ 79)}{100}}\quad \Rightarrow \quad SE(\hat{p})\ =\ 4.1$$

- Then, the appropriate t-value from Appendix A is found (must use a t-value for a one-sided test; where α.= 0.10. The degrees of freedom are 99 (equal to n -1). The $t_{\alpha,df}$ value is 1.290.

- The one-sided 90% confidence interval is calculated using the following equation:

$$\text{Confidence Interval}\ =\ \hat{p}\ +\ [t_{\alpha,df}\ X\ SE(\hat{p})]$$

Confidence Interval = 79 + [1.290 X 4.1] = 79 $\pm$ 5.3

- Therefore, we are 90 percent certain (with a one-sided test) that the true mean of the ground cover is somewhere within 79.0 and 84.3%. The calculated 90% confidence interval exceeds the lowest acceptable value of 81.6%. Conclusion: for the ground cover parameter, the amount of cover estimated indicates that there **is** revegetation success.

Example 3. Ground cover for a postmining land use of pastureland, in a region with 40 inches of average annual rainfall. Revegetation success will be determined by comparing the ground cover of the reclaimed area to that from a reference area.

The survey method used was baseline sampling with multiple random starts. The cover measurements were obtained with a point frequency method, using a crosswire sighting device. Separate vegetation ground cover surveys were conducted on both areas. Ninety-two observations were taken in the reference area, while ninety-eight observations were obtained in the reclaimed area (the goal for ground cover measurements is 100 observation points; however, the actual sample number will be affected by transect dimensions and field conditions).

Survey Results (by area):
Reference Area
Observation points where vegetation was intercepted (“hits”): 89 of 92
Breakdown of vegetation hits

- All species: 86 of 89
    - ∗ Common bermudagrass 28 of 86
    - ∗ Coastal bermudagrass 18 of 86
    - ∗ Bahiagrass 13 of 86
    - ∗ Brownseed paspalum 5 of 86
    - ∗ Threeawn 6 of 86
    - ∗ Broomsedge bluestem 3 of 86
    - ∗ Little bluestem 4 of 86
    - ∗ Switchgrass 1 of 86
    - ∗ Pricklypear 2 of 86
    - ∗ Woolly croton 5 of 86
    - ∗ Sunflower 2 of 86
    - ∗ Yucca 2 of 86
- Litter: 3 of 89

Observation points where bare ground intercepted (“misses”): 3 of 92

Reclaimed Area
Observation points where vegetation was intercepted (“hits”): 91 of 98
Breakdown of vegetation hits

- Permit-approved species: 79 of 91
    - ∗ Common bermudagrass 27 of 79
    - ∗ Kleingrass 44 of 79
    - ∗ Bahiagrass 1 of 79
    - ∗ Switchgrass 7of 79
- Litter: 1 of 93
- Other species found in reference area (broomsedge bluestem and sunflower): 4 of 91
- Non permit-approved species: 7 of 91

Observation points where bare ground intercepted (“misses”): 7 of 98

Ground Cover Calculations

Reference Area

The estimated ground cover was 96.7% (89 of 92).

Reclaimed Area

The estimated ground cover was 85.7% (84 of 98).

- Vegetation hits were 84 of 98 (instead of 91 of 98, because we excluded 7 vegetation "hits" that were comprised of non permit-approved undesirable species)

Statistical Comparison to Reference Area

The statistical comparison allows us to determine whether the reclaimed area ground cover is statistically no less than 90% of the ground cover in the reference area. A Z-test statistic is used.

- Calculate the lowest acceptable value by multiplying the percent ground cover of the reference area by 0.9 -- resulting in a value of 87%.
- The reclaimed area ground cover (85.7%) is less than the lowest acceptable value (87%); therefore, a Z-test must be performed.
- The first step is to calculate the pooled standard error of the two binomial proportions:

$$SE(\hat{p}_1 - \hat{p}_2) = \sqrt{\frac{\hat{p}_1(100 - \hat{p}_1)}{n_1} + \frac{p_2(100 - \hat{p}_2)}{n_2}}, \quad \text{where}$$

- $\hat{p}_1$ is the reference area percent ground cover
- $\hat{p}_2$ is the reclaimed area's ground cover proportion
- n_1 is the number of observations taken in the reference area
- n_2 is the number of observations taken in the reclaimed area

$$SE(\hat{p}_1 - \hat{p}_2) = \sqrt{\frac{96.7(1 - 96.7)}{92} + \frac{85.7(1 - 85.7)}{98}}$$

$$SE(\hat{p}_1 - \hat{p}_2) = \sqrt{\frac{319}{92} + \frac{1225}{98}} \qquad SE(\hat{p}_1 - \hat{p}_2) = 4.0$$

- Finally, calculate the Z test statistic. The test statistic (Z) is equal to the difference between lowest acceptable value (90% of the reference area ground cover) and the reclaimed area ground cover, divided by the pooled standard error of the binomial data from both areas.

$$\text{Calculated } Z = \frac{0.9\hat{p}_1 - \hat{p}_2}{SE(\hat{p}_1 - \hat{p}_2)}$$

$$\text{Calculated } Z = \frac{87.0 - 85.7}{4.0} \qquad \text{Calculated } Z = 0.32$$

The null hypothesis is that the reference area value is equal or less than the reclaimed area value. The null hypothesis is rejected if the calculated Z is greater than 1.28 (the null hypothesis is rejected if the calculated Z is greater than 1.28. The null hypothesis is not rejected if the calculated Z is equal to or less than 1.28. Conclusion: for the ground cover parameter, The Z test for the cover estimates indicates that the reclaimed area meets the revegetation success standard, since the null hypothesis was not rejected.

Productivity – Herbaceous Biomass

Example 1. Productivity for a postmining land use of grazingland, in a region with 23 inches of average annual rainfall. The revegetation success will be determined by comparing the ground cover of the reclaimed area to that from a reference area.

The survey method used was baseline sampling with multiple random starts. The forage sampling locations were obtained when conducting concurrent ground cover measurements. Separate productivity evaluations were conducted on both areas. Quadrat size for clipping was 0.5 m^2 (equivalent to a square with 2.32-foot sides).

Survey Results and Calculations (by area):

A statistically adequate sample size must be determined for both the reference area and the reclaimed area. It is determined by calculating the variance of the field sample weights taken in each area.

It is necessary to ascertain that enough samples have been taken, while still in the field, by calculating the statistically adequate sample size, using the equation below:

$$N = \frac{(s^2 \times t^2)}{(d \times \bar{x})^2}, \quad \text{where:}$$

- N = total number of sample required
- s^2 = variance
- $\bar{x}$ = the mean (average) of undried weights
- t = t-value for one-sided test with 90% confidence (where α = 0.10), see table in Appendix A for the appropriate t-values. The degrees of freedom to use are equal to n - 1.
- d = the desired precision (maximum error relative to the mean); d = 0.1 for 10%.

Reference Area

The ground cover and quantities of herbaceous growth within the reference area appeared variable, but an initial sampling of 15 locations was conducted anyway (more samples should have been taken with the apparent variability that was noticed -- the statistically adequate sample test, after the initial samples are taken, will indicate if 15 initial samples were acceptable). Individual field sample weights were employed to determine the statistically adequate sample size (final, oven-dry weights for estimating actual yields are obtained after oven-drying vegetation samples at 60^o C until the sample weights stabilize). Field samples must be weighed as soon as possible, in order to obtain accurate field weights (before moisture loss occurs).

The sample weights for the initial sampling are found in Table B-1.

Table B-1. Initial observations for reference area, Example 1, herbaceous productivity.

Observation Point	Field Weight, gms	$(x - \bar{x})$	$(x - \bar{x})^2$
1	750	-239	57,100
2	760	-229	52,400
3	550	-439	192,700
4	1550	561	314,700
5	1700	711	505,500
6	840	-149	22,200
7	600	-389	151,300
8	770	-219	48,000
9	1020	31	1,000
10	1200	211	44,500
11	1350	361	130,300
12	1150	161	25,900
13	840	-149	22,200
14	750	-239	57,100
15	1000	11	121
	Mean = 989		1,625,021

From Calculator with Statistical Functions:

Standard Deviation (s) = 341 gms
Variance (s^2) = 116,100 gms

or

By Hand-calculating:

$s^2 = \Sigma(X - X)^2 / (n - 1)$
$= (1,625,021) / (15 - 1)$
$= 116,100$

Next, determine whether a statistically adequate sample has been obtained, by calculating the needed sample size (N), using the formula below:

$$N = \frac{(116,100 \times 1.761^2)}{(0.1 \times 989)^2} = 37.$$

The result indicates that 37 measurements are needed in order to obtain an acceptable mean value; therefore, it appears that 22 additional measurements would be needed. An acceptable approach would be to collect 15 samples and recalculate the statistically adequate sample size at that point, since there is a possibility that it may be met at the 30-sample point. If a statistically adequate sample has not been obtained after taking 30 samples, the data is too variable and will not be accepted by the Commission.

The sample weights for the second sampling set are found in Table B-2 (table includes the sample weights from the 1st set of samples).

Table B-2. Results after 2^{nd} set of observations collected, Example 1, herbaceous productivity.

Observation Point	Field Weight, gms	Observation Point	Field Weight, gms
1	750	16	1400
2	760	17	1150
3	550	18	720
4	1550	19	660
5	1700	20	1050
6	840	21	990
7	600	22	1460
8	770	23	1130
9	1020	24	720
10	1200	25	560
11	1350	26	1350
12	1150	27	830
13	840	28	930
14	750	29	1440
15	1000	30	700
(Initial 15 Samples)		(Additional Samples)	

From Calculator with Statistical Functions:

Standard Deviation = s = 319
Variance = s^2 = 101,761
Mean = 997

Next, determine whether a statistically adequate sample size has been obtained:

$$N = \frac{\left(101{,}176 \times 1.699^2\right)}{\left(0.1 \times 997\right)^2} = 29.$$

The result indicates that no more measurements are needed. Note: it is possible for a recalculated N value, resulting from additional sampling, to be less than the sample size calculated after initial sampling, since additional measurements may establish a lower variance for the area. All samples must be used for the necessary calculations (i.e. the 30 samples are used, not 29). Also, it is not acceptable to discard apparent outlier data in order to obtain a statistically adequate sample size.

Reclaimed Area

The ground cover and quantities of herbaceous growth within the reclaimed area appeared fairly uniform, so an initial sampling of 15 locations was conducted. Individual field sample weights were employed to determine the statistically adequate sample size (final, oven-dry weights for estimating actual yields are obtained after oven-drying vegetation samples at 60^o C until the sample weights stabilize).

The sample weights for the initial sampling are found in Table B-3.

Table B-3. Initial observations for reclaimed area, Example 1, herbaceous productivity.

Observation Point	Field Weight, gms	Observation Point	Field Weight, gms
1	660	9	990
2	920	10	930
3	760	11	730
4	800	12	820
5	710	13	1000
6	570	14	670
7	980	15	740
8	570		

From Calculator with Statistical Functions:

Standard Deviation (s) = 146 gms
Variance (s^2) = 21,316 gms
Mean = 790gms

Next, determine whether a statistically adequate sample size has been obtained:

$$N = \frac{\left(21{,}316 \times 1.761^2\right)}{\left(0.1 \times 790\right)^2} = 11.$$ The result indicates that no more measurements are needed.

The oven-dry sample weights must be obtained for both areas before a statistical comparison is made. Then, the units of the oven-dry biomass weights from each observation point (quadrat) must be converted to lb/acre units. Multiply the quadrat weights (grams/0.5 m^2) by 17.7 to obtain yields in lbs/acre.

Table B-4. Oven-dry weights for both areas, Example 1, herbaceous productivity.

Reference Area						Reclaimed Area		
Field Weight, gms/m^2	Oven-dry Moisture Content	Oven-dry Weight, lbs/acre	Field Weight, gms/m^2	Oven-dry Moisture Content	Oven-dry Weight, lbs/acre	Field Weight, gms/m^2	Oven-dry Moisture Content	Oven-dry Weight, lbs/acre
750	89	1,460	1,400	90	2,478	660	89	1,285
760	90	1,345	1,150	89	2,239	920	88	1,954
550	89	1,071	720	91	1,147	760	88	1,614
1,550	89	3,018	660	88	1,402	800	89	1,558
1,700	89	3,310	1,050	88	2,231	710	88	1,508
840	90	1,487	990	89	1,928	570	90	1,009
600	88	1,274	1,460	90	2,584	980	89	1,908
770	89	1,499	1,130	89	2,200	570	88	1,211
1,020	89	1,986	720	88	1,529	990	89	1,928
1,200	88	2,549	560	88	1,189	930	88	1,976
1,350	90	2,389	1,350	90	2,389	730	88	1,551
1,150	89	2,239	830	88	1,763	820	88	1,742
840	89	1,882	930	88	1,975	1,000	90	1,770
750	88	1,593	1,440	90	2,549	670	89	1,305
1,000	89	1,947	700	88	1,487	740	88	1,572

Reference Area Data:
Mean = 1,938 lbs/acre
Standard Deviation = 570 lbs/acre
Variance = 324,900

Reclaimed Area Data:
Mean = 1,592 lbs/acre
Standard Deviation = 295 lbs/acre
Variance = 87,025

Even though the field ("wet") weights from both areas were used to obtain statistically adequate sample sizes, it is necessary to confirm that the final oven-dry data also constitute a statistically adequate sample.

- Statistically adequate sample size for reference area:
  30 observations; therefore t-value (for two-sided test) is 1.699
  N must be less than 30:

$$N = \frac{\left(324{,}900 \times 1.699^2\right)}{\left(0.1 \times 1{,}938\right)^2} = 24.9$$

- Statistically adequate sample size for reclaimed area:
  15 observations; therefore t-value (for two-sided test) is 1.761
  N must be less than 15:

$$N = \frac{(87{,}025 \times 1.761^2)}{(0.1 \times 1{,}592)^2} = 10.6$$

<u>Statistical Comparison to Reference Area</u>
A t-test is necessary because the reclaimed area productivity (1,592 lbs/acre) is less than the lowest acceptable value of 1,744 lbs/acre (90% of the reference area productivity). The null hypothesis is that the that the reference area mean productivity is equal or less than the reclaimed area mean productivity. The null hypothesis is rejected if the calculated t-value is greater than the appropriate t-value from Table A-1. The null hypothesis is not rejected if the calculated t-value is equal to or less than the t-value from Table A-1.

The hypothesis test is based on a two-sample comparison for small samples (where sample number is ≤ 30). The test statistic follows:

$$\text{Calculated t-value} = \frac{[0.9\bar{x}_1 - \bar{x}_2]}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where $0.9\bar{x}_1$ is the lowest acceptable value (90% of the mean yield of the reference area), $\bar{x}_2$ is the mean yield of the reclaimed area, s_1^2 is the variance of the reference area, s_2^2 is the variance of the reclaimed area, n_1 and n_2 are the sample sizes for the reference and reclaimed areas, respectively.

$$\text{Calculated t-value} = \frac{[(0.9 \text{ X } 1{,}938) - 1{,}592]}{\sqrt{\frac{324{,}900}{30} + \frac{87{,}025}{15}}} = 1.18$$

The next step is to select the appropriate t-value from Table A-1, in order to compare the calculated t-value to it. We know that the t-value will be found in the one-sided test column; however, we must have the correct degrees of freedom before we can obtain the t-value. A comparison of the variances from both areas will allow us to use the correct method of estimating the degrees of freedom. If the variances are equal, the following equation is used to estimate the degrees of freedom:

$$\text{degrees of freedom} = n_1 + n_2 - 2$$

However, in this example, the variances are not equal. Therefore, the following equation must be used to estimate the degrees of freedom (Helsel and Hirsch, 1992):

$$\text{degrees of freedom (d.f.)} = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\left(\frac{s_1^2/n_1}{n_1 - 1}\right)^2 + \left(\frac{s_2^2/n_2}{n_2 - 1}\right)^2}$$

$$\text{(d.f.)} = \frac{\left(\frac{324{,}900}{30} + \frac{87{,}025}{15}\right)^2}{\left(\frac{324{,}900/30}{29}\right)^2 + \left(\frac{87{,}025/15}{14}\right)^2} = 43$$

NOTE: The degrees of freedom were the same for either of the equations. This may happen when there are a larger number of samples involved (>15). Nevertheless, the second equation for determining degrees of freedom should be used when the variances are unequal.

The one-sided test t-value for 43 degrees of freedom is 1.301. The null hypothesis is not rejected because the calculated t-value (1.18) is less than 1.301. Conclusion: the reclaimed area would meet the revegetation success standard for the productivity parameter, since the null hypothesis was not rejected.

***Example 2*.** Productivity for a postmining land use of pastureland, in a region with 36 inches of average annual rainfall. The revegetation success criteria will be based on technical standards, since a reference area was not used. The required information on precipitation, soils, and other pertinent factors needed to estimate the technical standards are included in the section covering the statistical comparison to the technical standard.

The survey method used was baseline sampling with multiple random starts. The forage sampling locations were obtained when conducting concurrent ground cover measurements. Quadrat size for clipping was 0.25 m^2 (equivalent to a square with 1.64-foot sides).

Survey Results and Calculations

The statistically adequate sample size must be determined for the reclaimed area. It is determined by calculating the variance of the field sample weights taken.

This example will use the statistically adequate sample formula to ascertain that enough samples have been taken and estimate, if needed, how many additional samples would be required to obtain a statistically adequate sample size.

Equation used to determine the statistically adequate sample size:

$$N = \frac{\left(s^2 \times t^2\right)}{\left(d \times \overline{x}\right)^2}, \quad \text{where:}$$

* N = total number of sample required
* s^2 = sample variance
* $\overline{x}$ = the mean (average) of undried weights
* t = t-value for two-sided test with 90% confidence, see table in Appendix A (degrees of freedom to use are equal to n - 1).
* d = the desired precision (maximum error relative to the mean); d = 0.1 for 10%.

The ground cover and quantities of herbaceous growth within the reclaimed area appeared to be consistent, so an initial sampling of 15 locations was conducted. Individual field sample weights were employed to determine that statistically adequate sample size (final, oven-dry weights for estimating actual yields are obtained after oven-drying vegetation samples at 60^o C until the sample weights stabilize). Field samples must be weighed as soon as possible, in order to obtain accurate field weights (before moisture loss occurs).

The sample weights for the initial sampling are found in Table B-5.

Table B-5. Initial observations for reclaimed area, Example 2, herbaceous productivity.

Observation Point	Field Weight, gms	Observation Point	Field Weight, gms
1	320	9	350
2	370	10	275
3	420	11	410
4	400	12	360
5	475	13	380
6	375	14	400
7	350	15	400
8	425		

From Calculator with Statistical Functions:

Standard Deviation (s) = 48 gms
Variance (s^2) = 2,304 gms
Mean = 381 gms

Next, determine whether a statistically adequate sample size has been obtained:

$$N = \frac{\left(2{,}304 \times 1.761^2\right)}{\left(0.1 \times 381\right)^2} = 5.$$ The result indicates that no more measurements are needed.

The oven-dry sample weights must be obtained before a statistical comparison is made. Then, the units of the oven-dry biomass weight from each observation point (quadrat) must be converted to lb/acre. Multiply the quadrat weights (grams/0.25 m^2) by 35.7 to obtain yields in lbs/acre.

The oven-dry weights must be standardized to the same moisture content as the technical standard (Table 6), with the following equation:

$$\text{Oven-Dry Weight} \Big/ \left(\frac{100 - \text{Standardized Oven-Dry Moisture Content}}{100} \right) = \text{Standardized Weight}$$

Table B-6. Oven-dry weights for reclaimed area, Example 2, herbaceous productivity.

Observation Point	Field Weight, gms	Oven-Dry Moisture Content, %	Oven-Dry Weight, lbs/acre	Standardized Weights to 15% Moisture
1	320	85	1714	2016
2	370	84	2113	2486
3	420	83	2549	2999
4	400	86	1999	2352
5	475	85	2544	2993
6	375	85	2008	2362
7	350	86	1749	2058
8	425	84	2428	2856
9	350	85	1874	2205
10	275	82	1767	2079
11	410	86	2049	2411
12	360	84	2056	2419
13	380	84	2171	2554
14	400	85	2142	2520
15	400	85	2142	2520

From Calculator with Statistical Functions:

Standard Deviation = 310
Variance = 96,100
Mean = 2,455 lbs/ac
Mean Standardized Weight = 1.2 tons/acre

Even though the field ("wet") weights constituted a statistically adequate sample, it is necessary to confirm that the final oven-dry data also produce a statistically adequate sample size.

- Statistically adequate sample size for reclaimed area:
  15 observations; therefore t-value (for two-sided test) is 1.761
  N must be less than 15:

$$N = \frac{(96{,}100 \times 1.761^2)}{(0.1 \times 2{,}455)^2} = 4.9$$

Statistical Comparison to Technical Standard

The technical standard is derived from the relationship between the vegetation species, nitrogen (N) fertilizer application rates, and growing season precipitation and biomass yields. The following information is illustrative of the factors considered in the USDA-NRCS Technical Standard studies developed on a mine-specific basis:

Common bermudagrass growing in a sandy minesoil
N fertilizer applied: 120 lbs N/acre
Biomass yield per inch of precipitation: 1 ton per 8.9 inches
Growing season rainfall: 15 inches
Projected bermudagrass yield: 15 inches / (8.9 inches/ton) = 1.7 tons/acre
Technical Standard = 1.7 tons/acre

The estimated mean yield was 1.2 tons/acre, while the lowest acceptable value for productivity was 1.4 tons/acre (the technical standard); therefore, the calculation of a confidence interval **will be**

necessary. A one-sided 90% statistical confidence interval for the productivity estimate must be calculated in order to determine whether revegetation success has been achieved.

- First, the standard error of the estimated mean yield is calculated using the following equation:

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}} = \frac{310}{\sqrt{15}} = 80$$

- Then, the appropriate t-value from Appendix A must be found (must use a t-value for a one-sided test; where $\alpha = 0.10$. The degrees of freedom are 14 (equal to n -1). The $t_{\alpha,df}$ value is 1.345.

- The 90% confidence interval is calculated using the following equation:

$$\text{One-sided Confidence Interval} = \bar{x} + [t_{a,df} \text{ X } SE_{\bar{x}}]$$

$$\text{Confidence Interval} = 2{,}455 \pm [1.345 \text{ X } 80] = 2{,}455 \pm 108$$

$$\text{Confidence Interval} = 2{,}455 \text{ to } 2{,}563 \text{ lbs/acre} = 1.2 \text{ to } 1.3 \text{ tons/acre}$$

- Therefore, we are 90 percent certain (with a one-sided test) that the true mean of bermudagrass yield is somewhere within 1.2 and 1.3 tons/acre. The calculated one-sided 90% confidence interval is less than the lowest acceptable value of 1.4 tons/acre. Conclusion: the amount of estimated bermudagrass production **does not** indicate revegetation success.

Woody Plant Stem Count

Example 1. Woody plant stem count for a postmining land use of fish and wildlife habitat, in south Texas. The revegetation success criteria will be based on technical standards, since a reference area is not used in the fish and wildlife habitat land use. After consultation with the Texas Parks and Wildlife Department, the following technical standards were established: 300 stems/acre of native brush species in stands consisting of blocks, corridors, or mottes.

The survey method used was baseline sampling with multiple random starts. The woody-plant stem count measurement locations were obtained when conducting concurrent ground cover measurements. The plot size for stem count measurements was 1257 ft^2 (a circle with a radius of 20 feet, with the radius delineated by a tape or rope), equal to 0.0288 acres.

Survey Results and Calculations

The area appeared to be somewhat uniform, so an initial sampling of 15 plots was conducted. The data collected by the vegetation survey is shown in Table B-7.

Table B-7. Initial observations for reclaimed area, Example 1, stem count productivity.

Observation Point	Stem Count per Plot	Observation Point	Stem Count per Plot
1	8	9	9
2	9	10	6
3	5	11	7
4	8	12	8
5	9	13	6
6	10	14	6
7	8	15	7
8	7		

From Calculator with Statistical Functions:

Standard Deviation = 1.4 stems
Variance = 1.96 stems
Mean = 7.5 stems

Next, determine whether a statistically adequate sample size has been obtained:

$$N = \frac{\left(1.96 \times 1.761^2\right)}{(0.1 \times 8.4)^2} = 11.$$

The result indicates that 11 measurements are needed in order to obtain an acceptable mean value; therefore, no more measurements are needed.

The stem count/acre must be obtained before a statistical comparison can be made with the technical standard. Multiply the stem count / 0.0288 acre by 34.7 to obtain stem counts per acre:

Mean stem count = 7.5 stems / 0.0288 acre X 34.7 = 260 stems/acre
Standard Deviation of Stem Count = 1.4 X 34.7 = 48.6 stems/acre

Statistical Comparison to Technical Standard

The estimated stem count per acre was 260, while the lowest acceptable value for stems/acre was 270 (90 percent of the 300 stems/acre technical standard); therefore, the calculation of a confidence interval **will be necessary**. A one-sided 90% statistical confidence interval for the stem count estimate must be calculated in order to determine whether revegetation success has been achieved.

- First, the standard error of the estimated mean yield is calculated using the following equation:

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}} = \frac{48.6}{\sqrt{15}} = 12.5$$

- Then, the appropriate t-value from Appendix A must be found (must use a t-value for a one-sided test, where α = 0.10. The degrees of freedom are 14 (equal to n -1). The $t_{\alpha,df}$ value is 1.345.

- The 90% confidence interval is calculated using the following equation:

$$\text{One-sided Confidence Interval} = \bar{x} + [t_{a,df} \times SE_{\bar{x}}]$$
$$\text{Confidence Interval} = 260 + [1.345 \times 12.5] = 260 + 17$$
$$\text{Confidence Interval} = 260 \text{ to } 277 \text{ stems/acre}$$

Therefore, we are 90 percent certain (with a one-sided test) that the true mean of the stem count/acre is somewhere between 260 and 277 stems/acre. The calculated 90% confidence interval exceeds the lowest acceptable value of 270 stems/acre. Conclusion: the estimated mean stem count indicates that there **is** revegetation success, for the productivity parameter.

Example 2. Woody plant stem count for a postmining land use of forestry, in east Texas. The revegetation success criteria will be based on a technical standard. After consultation with the Texas Forest Service, the following technical standards were established for pine production: 540 stems/acre.

The survey method used was baseline sampling with multiple random starts. The woody plant stem count measurement locations were obtained when conducting concurrent ground cover measurements. The plot size for stem count measurements was 452 ft^2 (a circle with a radius of 12 feet, with the radius delineated by a tape or rope), equal to 0.0104 acres.

Survey Results and Calculations

The area appeared to be fairly uniform, so an initial sampling of 15 plots was conducted.

Table B-8. Initial observations for reclaimed area, Example 2, stem count productivity.

Observation Point	Stem Count per Plot	Observation Point	Stem Count per Plot	From Calculator with Statistical Functions:
1	5	9	4	
2	6	10	7	Standard Deviation = 1.2 stems
3	7	11	8	Variance = 1.4 stems
4	5	12	6	Mean = 6.0 stems
5	6	13	7	
6	6	14	8	
7	5	15	5	
8	5			

Next, determine whether a statistically adequate sample size has been obtained:

$$N = \frac{\left(1.4 \times 1.761^2\right)}{\left(0.1 \times 6.0\right)^2} = 12.$$

The result indicates that 12 measurements are needed in order to obtain an acceptable mean value; therefore, no more measurements are needed.

The stem count/acre must be obtained before a statistical comparison can be made with the technical standard. Multiply the stem count per 0.0104 acre by 96 to obtain the stem count per acre:

Mean stem count = 6.0 stems / 0.0104 acre X 96 = 576 stems/acre
Standard Deviation of Stem Count = 1.2 X 96 = 115 stems/acre

Statistical Comparison to Technical Standard

The estimated stem count per acre for the reclaimed area was 576. This value was greater than the lowest acceptable value of 486 stems/acre (90 percent of the 540 stems/acre technical standard); therefore, the calculation of a confidence interval **will not** be necessary. The estimated mean stem count indicates that there **is** revegetation success.

Attachment 1

USDA-NRCS - The Development of the

Forage Production Standards for Post Mine Soils

THE DEVELOPMENT OF THE FORAGE PRODUCTION STANDARDS FOR POST MINE SOILS

Introduction

There are numerous characteristics that are important in soil productivity as it affects a specific crop or land use. Considerable research, clipping data, demonstrations, and observations have been conducted evaluating relationships between yield, weather variables and soil parameters. These data indicate yields may vary considerably according to defined soil limitations.

Important considerations include soil texture, which is associated with many of the chemical and physical reactions, and soil structure, which influences air, water, and root penetration. Other characteristics such as available water capacity and exchange capacity, largely determined by texture, have a great influence on productivity.

In addition to soil characteristics, the soil's position on the landscape, its slope gradient, and other special features affect potential production with constant climate and management inputs. While soils which react similarly can be grouped, each soil series and class-determining phase should be independently considered.

The initial step in forage production standard development was to determine soil series and mapping units to be mined. Soil surveys were used to record all mapping units for each mine site.

The next step involves forage species. For the mine site, forage species to be planted need to be identified.

To establish benchmark yields, production data from published soil surveys, soil interpretation records, pasture and hayland suitability group descriptions, and grazing group descriptions were used. For pasture and hayland, these yields are usually recorded as projected yields from a high management level. Yields for grazingland are recorded as pounds of forage for favorable, normal or unfavorable years.

Forage Production Standards

The production of forage is largely dependent on management inputs and climate factors. Of primary importance is the yield relationship to fertilizer and available moisture.

The benchmark yields were grouped for evaluation based on specific management levels. Each level assumed (1) full stand establishment; (2) efficient harvesting; (3) effective control of insects, weeds, and disease; and (4) where needed, the application of soil conservation measures.

Additionally, management levels used were based on average fertilizer applications used in the area surrounding each mine site.

Local research, demonstrations, and experience relating to soil-forage-moisture response to management was then used to establish predicted yields for each management level by soil mapping unit, species, and land use. These yields were based on average rainfall amounts and distribution.

By identifying specific fertility levels for a given predicted yield, typical response curves were prepared. These curves reflect the response of a species production (yield) to applied fertility in an average climate regime. Additional curves were developed to correlate rainfall with yields at varying fertility levels.

The resulting production standards are those expected for average rainfall amounts and distribution for a specific fertility program. To account for soil variations which affect productivity, standards were identified by soil mapping units. Mapping units were grouped where soil characteristics allowed similar response. Through the use of rainfall data, correlating with yields, procedures were developed to adjust predicted yields in years of below average rainfall amounts or distribution.

Species Response to Fertilization

Extensive research on the response of fertilization has been conducted in Texas and at numerous locations in the south. The research data indicate the yield increase for each additional unit of nitrogen applied for selected species. These data have been used to develop predictive yield curves for average climate conditions.

Species Response to Water

Water use efficiency of forage species is closely related to fertilizer levels. Water use efficiency has been reported in research work at various locations. This work indicates that as fertilizer levels increased, the amount of water required to produce a ton of forage significantly decreased. This decrease tends to stabilize somewhat as the typical response to fertilizer decreases. The consistent results at various locations and years provide a guideline for predicting the response of selected species to fertilization under a particular set of climate conditions.

While the responses of grass species to fertilization and water use can be used to predict annual yields, the total available moisture during the growing season and the number of rainfall events during the growing season have the greatest effect on annual yields in non-irrigated locations. The effectiveness of rainfall under various fertilizer levels has been compiled from research work done in various locations in Texas and the south. Total annual rainfall, growing season rainfall, and monthly rainfall records were used with corresponding research work at specific locations to develop a response curve of rainfall, fertilizer, and yields for highly adapted soils for specific forage species.

Table I provides the relationship of forage species on highly adapted soils to rainfall during the growing season at varying nitrogen levels with other nutrients in proper balance. It is applicable to the total amount of rainfall during the growing season and also relates to the response for each rainfall event during the growing season.

Establishing Technical Standards for Forage Production

To account for soil properties or soil positions on the landscape which influence yield potential, each soil unit was evaluated as to its relative productivity. Table II provides the relative productivity of each soil series and class-determining phase if yield potential would vary between phases for each identified forage species.

The resulting production standards reflect the minimum expected production for average growing season rainfall amounts and distribution and temperature for the mine site. The standards consider normal annual climate variations. An example showing calculated forage production standards is shown in Table III.

While native legume species may be planned and may be included in plantings, their contribution to forage production is primarily to extend the growing season of a mixed plant community. Because these species have the capability of nitrogen fixation, a relationship of fertility to yields is not available. The use of native legumes and/or forbs under fertilized conditions will not significantly influence forage yield production standards.

ESTIMATING FORAGE PRODUCTION STANDARDS

While the production standards account for climate variations during a growing season, the data available can be used to adjust production potential in years when rainfall during the growing season exceeds normal variations expected. Table I data provide for the response of forage species to rainfall at varying nitrogen levels with other nutrients in proper balance.

Data used to develop the response curves for forage species include data accounting for yields when growing season rainfall was 5.5 inches, to yields in years when rainfall during the growing season was 38.6 inches. Data for lower amounts of growing season rainfall are not available and yields from rainfall amounts greater than 38.6 inches do not reflect an increase in production.

In adjusting yields to account for actual growing season rainfall Table I should be used to establish the inches of rainfall required to produce a ton of forage for a determined fertility input. Total actual rainfall amounts during the growing season should then be used to determine the production expected for each species. Table II should be used to determine soil productivity of the specific soils in the area being evaluated. Relative percentage of species and soils should be determined. The weighted averages of species and soils should be used to determine expected production. This would reflect the adjusted production standard for the site.

If the recorded growing season rainfall is less than 5.5 inches or greater than 38.6 inches the forage production standards should not be used.

TABLE I

RELATIONSHIP OF RAINFALL AND FERTILITY ON YIELDS OF FORAGE SPECIES

Nitrogen Pounds/Acre	Forage Species – Inches of Growing Season Rainfall Per Ton of Forage					
	Coastal Bermuda Grass	Improved Bluestem	Kleingrass	Switch Grass	Common Bermuda Grass	Little Bluestem
0	14.1	12.9	12.9	11.7	18.3	12.9
20	12.1	11.7	10.9	10.0	15.7	12.1
40	10.5	10.6	10.0	9.2	13.6	10.4
60	9.2	9.3	8.9	8.0	11.9	9.6
80	8.2	8.3	8.0	7.4	10.6	8.5
100	7.4	7.8	7.2	6.8	9.8	8.0
120	6.6	7.1	6.7	6.3	8.9	7.2
140	5.8	6.9	6.3	5.8	8.8	6.6
160	5.3	6.5	5.9	5.4	7.7	6.3
180	4.9	6.0	5.6	5.1	7.3	6.0
200	4.6	5.8	5.4	4.9	7.1	5.8
220	4.3	5.8	5.4	4.8	7.0	5.7
240	4.0	5.7	5.3	4.7	6.9	5.7
260	3.9	5.6	5.3	4.6	6.8	5.7
280	3.8	5.6	5.2	4.6	6.7	5.6
300	3.8	5.5	5.2	4.5	6.7	5.6

TABLE II

RELATIVE PRODUCTIVITY - SOIL MAPPING UNITS

Soil Mapping Unit	Relative Productivity (Percent)					
	Coastal Bermuda Grass	Improved Bluestem	Kleingrass	Switch Grass	Common Bermuda Grass	Little Bluestem
Uhland, ff	100	100	100	100	100	100
Rader lfs, 1-3%	95	100	95	100	90	100
Rader-Mabank	95	95	90	95	85	95
Crockett fsl, 1-3%	90	85	90	90	80	90
Rosanky lfs, 1-%	90	85	90	90	80	90
Normangee cl, 1-3%	85	90	85	85	80	80
Silstid lfs, 1-3%	85	80	80	80	75	85
Edge fsl, 2-5%	80	70	70	75	70	80
Edge fsl, 2-5% e	70	80	90	65	75	70
Padina fs, 1-6%	60	70	80	85	65	80
Edge, gullied	40	40	40	40	40	40
Jedd vgsl, 3-15%	40	40	40	40	40	40

TABLE III

EXAMPLE OF PRODUCTION STANDARDS FOR SPECIFIC FORAGE SPECIES
(VARYING FERTILITY LEVELS ON HIGHLY PRODUCTIVE SOILS)

Nitrogen Pounds/Acre	Forage Species – Fields in Tons Per Acre Per Year					
	Coastal Bermuda Grass	Improved Bluestem	Kleingrass	Switch Grass	Common Bermuda Grass	Little Bluestem
0	1.4	1.5	1.5	1.7	1.1	1.5
20	1.6	1.7	1.8	2.0	1.3	1.6
40	1.9	1.9	2.0	2.2	1.5	1.9
60	2.2	2.1	2.2	2.5	1.7	2.1
80	2.4	2.4	2.5	2.7	1.9	2.3
100	2.7	2.5	2.8	2.8	2.0	2.5
120	2.0	2.8	3.0	3.1	2.2	2.8
140	3.4	2.9	3.1	3.4	2.3	3.0
160	3.7	3.0	3.4	3.7	2.6	3.1
180	4.0	3.3	3.5	3.9	2.7	3.3
200	4.3	3.4	3.7	4.0	2.8	3.4
220	4.6	3.4	3.7	4.1	2.8	3.5
240	5.0	3.5	3.7	4.2	2.9	3.5
260	5.1	3.5	3.8	4.3	2.9	3.5
280	.2	3.6	3.8	4.4	3.0	3.5
300	5.3	3.6	3.8	4.4	3.0	3.5

Growing season rainfall for this example is 19.82 inches (March through September).

Attachment 2

Texas Parks and Wildlife Department

Recommendations for the Development of Success Standards for Woody-Plant Stocking Rates

(Revised June 14, 2006)

Texas Parks and Wildlife Department (TPWD) Recommendations for the Development of Success Standards for Woody-Plant Stocking Rates

All of the following are excerpts from a TPWD letter sent to the Commission on February 3, 1995, by Dr. Ray C. Telfair, II.

The attached information is a result of consultation with Department Staff and representatives of several mining companies.

There are concerns that while a program-wide system of minimum standards may allow the establishment of a regulatory program that might be easier to administer, such a program may not necessarily assure optimum habitat conditions for wildlife. The permit-specific option would not prevent changes to stocking rates and would allow fine-tuning of specific revegetation efforts based on localized conditions which can be highly variable. Establishing minimum program-wide stocking rates will likely create situations where specific, localized conditions would dictate higher planting densities than the minimum standards require. In these cases, optimum habitat conditions would not be created and wildlife populations would be suppressed.

Minimum Woody Vegetation Stocking Rates

General Wildlife Land Type Category	*Stocking Rates/Planting Standards*
Hardwood: (See Note 1)	
East Texas Blocks, Corridors, and Mottes	100 stems per acre
East Texas Fence Rows	6 stems per 100 linear feet
Central Texas Blocks, Corridors, and Mottes	30 stems per acre
Central Texas Fence Rows	10 stems per 100 linear feet
Native Brush:	
South Texas Blocks, Corridors, and Mottes	300 stems per acre
South Texas Fence Rows	10 stems per 100 linear feet
Fish & Wildlife Habitat-Bobwhite Quail and other Grassland Bird Species	*Stocking Rates/Planting Standards*
Native Brush: Statewide – Mottes	a. density of 2 mottes per acre b. mottes 30 – 50 feet in diameter c. 125 stems per motte or 250 stems per acre
Hardwood or Pine: Statewide	0 to a maximum 20 stems per acre

Note 1: Up to 30% of the planting standard can be pine. Longleaf pine is preferred, with native warm season grasses interspersed.

Planting Arrangements

Planting arrangements should be determined in accordance with habitat types (e.g., loafing area, escape cover, feeding cover, breeding sites, and corridors) within habitat designs (e.g., blocks, shelterbelts, and mottes).

Attachment 3

Texas Forest Service Recommendations for
Reforestation of Pine and Hardwoods in Texas

Texas Forest Service (TFS) Recommendations for Reforestation of Pine and Hardwoods in Texas

All of the following are excerpts from a TFS letter sent to the Commission on March 10, 1995, by Mr. Edwin H. Barron.

> *... monitoring reforestation performance. Please consider the inputs on the attached. These recommendations apply only to commercial forestland on mine reclamation sites.*

Recommended Optimum and Minimum Stocking Levels for Commercial Forestland on Mine Reclamation Sites

Time / Type of Trees		Optimum Stocking (stems/acre)	Minimum (stems/acre)
Initial Stocking	*(0 - 11 years)*		
Pines	East Texas	450 - 600	400 *
	Central Texas	350 - 550	300
Hardwoods	East Texas	350 - 500	250
	Central Texas	350 - 500	250
Stocking	*(12 - 20 years)*		
Pines	East Texas	300 - 400	250
	Central Texas	250 - 350	200
Hardwoods	East Texas	230 - 300	165
	Central Texas	230 - 300	165
Stocking			
Pines	*(21 - 30 years)*		
	East Texas	115 - 150	80
	Central Texas	115 - 150	80
Hardwoods	*(21 - 40 years)*		
	East Texas	100 - 125	80
	Central Texas	100 - 125	60

* Poor sites (SI - 65) 300 tree minimum.